Total Hip Arthroplasty in Young Patients An Orthopaedic Challenge

Daniël de Kam

Cover design: Daniël de Kam
Printed by: Ipskamp Drukkers, Enschede
The publication of this thesis was financially supported by:
Anna Fonds te Leiden, Bauerfeind Benelux, DePuy - Johnson & Johnson Medical BV, Merck Sharp and Dohme BV, Nederlandse Ortopaedische Vereniging, Oudshoorn chirurgische techniek bv, Reumafonds, Stryker Europe.

ISBN: 978-90-9026207-9

Total Hip Arthroplasty in Young Patients An Orthopaedic Challenge

Een wetenschappelijke proeve
op het gebied van Medische Wetenschappen

Proefschrift

Ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. mr. S.C.J.J. Kortmann
volgens besluit van het college van decanen
in het openbaar te verdedigen op donderdag 16 juni 2011
om 10:30 uur precies

Door

Daniël Cornelis Johan de Kam
geboren op 20 september 1983
te Vlissingen

Promotor
Prof. dr. R.P.H. Veth

Copromotoren
Dr. B.W. Schreurs
Dr. J.W.M. Gardeniers

Manuscriptcommissie
Prof. dr. J.A. Jansen
Prof. dr. P.L.C.M. van Riel
Prof. dr. R.G.T. Geesink, Maastricht UMC

Paranimfen
MSc. B.L.R. de Kam
Drs. J.J. Brunnekreef

Gratias tibi agimus, omnipotens Deus, pro omnibus beneficiis tuis.
Qui vivis et regnas per omnia saecula saeculorum.

Almachtige God, wij danken U voor Uw weldaden,
U, die leeft en heerst in de eeuwen der eeuwen.

Table of contents

Table of contents

Chapter 1

Introduction, general background and thesis outline

D.C.J. de Kam

Introduction

To relieve hip pain, restore the range of motion, and improve independency, almost 21.000 total hip arthroplasties (THA) are implanted each year in the Netherlands.[1] The incidence of osteoarthrosis of the hip is 27.000 cases per year and the Dutch government expects this number to increase by 52% over the period 2007 till 2040,[2] the expected consequence is that the number of THA will also increase. Fortunately, the THA is one of the most successful medical intervention in the world and is even called 'The operation of the century'.[3] Over more than half a century THA are implanted in older patients. In the last 3 decades THA are increasingly implanted in young patients because of these good results with older patients.[4,5] However, in young patients the results are more variable with higher failure rates reported.[6-12]

This thesis is about the technique and results of the total hip arthroplasty in young patients. The chapters will focus on the results of cemented THA in patients much younger than the average, older population with end stage hip diseases. Not only primary THA will be discussed, but also the outcome of revision THA in this demanding population will be studied. The content of the chapters will explain why THA in young patients are still an orthopaedic challenge.

History

The current concept of the THA has been popularized by Sir John Charnley in 1959 (Figure 1A-B).[13] Before this period it was custom to treat end-stage hip diseases with osteotomies of the pelvis or proximal femur, or by removal of the femoral head (a Girdlestone hip). In 1915 Murphy describes a new technique with the interposition of the fascia lata in the hip joint to relieve hip pain.[14] In 1923 Smith-Petersen performed a first trial of a hip replacement using a glass cup between the femoral head and acetabulum. As expected these glass cups soon failed, and he tried the same method with cups of bakelite and vitallium in 1937.[15] These cups were not fixated to the bone.

Total replacement of the femoral head was first described by the Judet brothers and Moore.[16,17] The Judet brothers used a metal reinforced plexiglass sphere, fixated in the femoral neck. Moore used the same concept, but used a prosthesis made of vitallium. Most of these prosthetic implants failed due to central migration through the medial acetabulum wall.

The first experiments of Charnley consisted of joint surface replacement with polytetrafluorethylene. Instant relief of pain was seen, but rapidly most patients

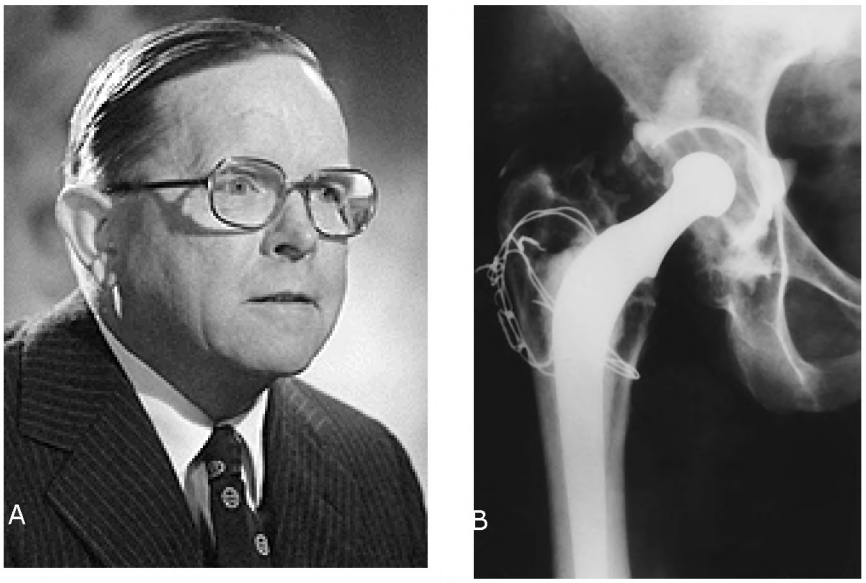


Figure 1A-B. Sir John Charnley (A) and the original low-friction arthroplasty designed by Sir Charnley (B).[13]

developed femoral head necrosis. After this failed attempt he replaced the entire femoral head with a metal implant and the acetabulum with a polytetrafluorethylene cup, the first concept of a THA.[13] Fixation of the implants to the bone was achieved with bone cement. The idea of cement fixation in orthopaedic implants came from Haboush.[18] In the fifties, he used dental cement for prosthetic fixation. His results were discouraging due to the design of the implant. In 1959 Charnley designed a new and better concept of his THA and in 1963 the polytetrafluorethylene was replaced by polyethylene because of the markedly fast wear. Still, this 50-year old design is one of the most successful implants in the current prosthesiology.[19,20]

Since then different concepts, improvements and ideas have been developed in an attempt to improve the (long-term) survival outcome of THA in young patients. First, in the sixties Ring implanted uncemented cups with screw fixation.[18] Ceramic components to reduce the rate of wear were first introduced by Mittelmeier in 1974.[21] Improvements of the cement fixation were investigated by Slooff, for example.[22,23] He replaced the original 'finger-packing' method of inserting the cement into the femoral canal by retrograde filling of the intramedullary canal with cement by using a cement syringe, the so called second generation cementing technique. In the last 4 decades many implant types and designs have been introduced on the market, each with their own advantages and disadvantages, different ways of fixation, shapes, and materials.

Current concepts

In general, two types of prosthetic fixation are being used: uncemented and cemented implants (Figure 2A-B). Stem fixation in uncemented implants is based on the bony ingrowth into or onto the surface of the implant. This can be enhanced with a porous coating or with bioinert or bioactive materials, like a hydroxyapatite coating. In cemented implants the function of the two-component acrylic bone cement that is being used is not to glue the implant to the bone, but rather filling the irregular gaps between the bone and implant, because a perfect anatomical fit is not possible. The optimal shape of the femoral component in cemented implants should transmit both torsional as well as axial load through the cement layer and bone, without creating peak stresses and without micro movements which could damage the cement layer or bone. Two types of stem designs are used in cemented implants to achieve these goals: the 'loaded-taper' or 'forced-closed' designs and the 'composite-beam' or 'shaped-closed' fixation.[24-26] Taper-closed based stems should have a highly polished surface and are allowed to subside some millimetres within the cement mantle. Shape-closed designs do bind rigidly to the cement because movement of these stems within the cement mantle might result in damage of the cement which can result in loosening of the stem.

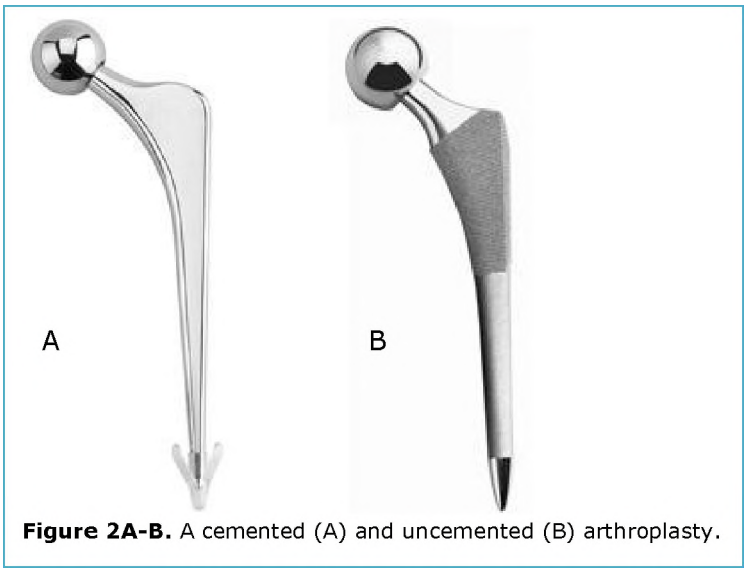


Figure 2A-B. A cemented (A) and uncemented (B) arthroplasty.

Cup fixation can also be based on these two ways of fixation. The cemented cups are inserted in the acetabulum after removing the cartilage and sclerotic bone using a reamer, next the PMMA cement is pressurized in the acetabular bone and the cup is placed. Uncemented implants can be inserted with different techniques. Primary stability of press-fit cups is achieved with direct contact of a slightly over-sized cup within the under-reamed acetabulum. Another technique is to use a screw-in cup, these cups have a threaded design and the cups are screwed into the acetabulum. In both types of uncemented cups, additional screws can be used to optimize primary stability. Long-term fixation is based on bony ingrowth into the rough surface in the same way as the femur.

Over time the original cementing technique has been changed. The first generation, so-called 'finger-packing', cementing techniques consisted of hand-mixing the two components in an open bowl. For the femur the cement was rolled by hand in the form of a doughy sausage and stuffed with a finger into the femoral canal before inserting the femoral stem. The cup was inserted in the acetabulum after a lump of cement was placed by hand in the prepared acetabulum.[13] In the past decades, several improvements have been made to create the current generation cementing technique[27]: the use of an intramedullary femoral plug to improve filling and cement-interface strength,[28] vacuum mixing of the cement to reduce porosity,[29,30] pressurizing the cement for better cement penetration,[31] the use of a modern cement gun for better filling and pressurisation,[22] and pulse lavage to clean the recipient bone bed.[27]

Young patients, why a challenge?

Because of the favourable results of THA in the elderly population surgeons have started to implant THA in young patients. However, obtaining the same satisfying long-term survival of THA in young patients remains challenging. At the moment, stem survival is acceptable in most studies in general, but the survival of the cup is the weakest link in patients younger than 40 years.[7,8,10,32-35] The reported differences in survival rates between the cup and stem are variable from 1% (97% [stem] versus 96% [cup][34]) in one study to 11% (98.3% [stem] versus 87.6% [cup][10]) in another study at 10 years. Despite attempts to improve cup designs and by using new materials, the acetabular component still shows lower survival rates than femoral implants.

Young patients must function longer with their THA than the typical elderly patient, and they are also engaged in higher levels of activity. This is associated with higher revision and reoperation rates.[36-40] Therefore, this population needs durable implants with excellent long-term survival.

Another underestimated factor which is very challenging in these young patients is the pathogenesis of the hip disease which leads to the decision to implant a THA. In the older population, primary osteoarthritis is the major indication for implantation of a THA. In young patients the pathogenesis is based on secondary osteoarthritis. Different diseases can cause secondary osteoarthritis: developmental dysplasia of the hips, rheumatoid arthritis, Perthes' disease, avascular necrosis, epiphyseal dysplasia, trauma, e.g. Most of these diseases are accompanied with bone stock loss of the acetabulum. This makes normal and stable implantation of the cup often very difficult and consequently obtaining a good long-term cup survival is becoming harder.

All these issues: higher activity levels, higher demands, and pre-existing bone stock loss make THA implantation in young patients with good long-term results a real orthopaedic challenge.

Bone Impaction grafting

In case of bone stock loss during difficult primary acetabular reconstruction or a femoral or acetabular revision, bone impaction grafting can be used to restore this deficiency. Bone impaction grafting is a reconstruction technique that biologically restores bone stock loss. The use of morselized bone grafts was published in the seventies by Hastings and Parker.[41] They reconstructed cavitar defects of the acetabulum in patients with

rheumatoid arthritis using morselized bone grafts and cementing a vitallium cup. McCollum et al. adapted this technique using wafers of bone.[42] Slooff et al. developed this technique into the current method of bone impaction grafting and introduced vigorous impaction of the grafts.[43]

The bone impaction grafting technique is performed as described below:

After resection of the femoral head, the acetabulum is prepared in the normal way, all cartilage, sclerotic bone and cysts are removed. Segmental defects of the acetabular rim and/or medial wall are first reconstructed with thin metal wire meshes, which are trimmed and adapted with special scissors and clamps to close the defect and contain the graft entirely. These meshes are fixated with several self drilling and tapping screws if needed (Stryker-Howmedica, Newbury, United Kingdom) (Figure 3A). When full containment with the wire meshes is achieved, a cavitary defect remains. Remaining sclerotic areas of the host bone are perforated with multiple small drill holes to enhance better vascularisation of the graft. The bone is cleaned using pulse lavage and trabecular bone chips of 0.7-1.0 mm are placed in the defect and impacted tightly using specially designed impactors (Figure 3B-C). The impactors increase in size and the size of the last used impactor responds to the size of the polyethylene cup with its cement layer.

Multiple layers of graft are impacted until the defect is completely solidly filled. A minimum layer of 5mm of impacted bone grafts is created. The bone chips are made of autograft and/or a combination of autograft and allogenic femoral heads. These femoral heads are morselized with a special bone mill or by hand using a large rongeur, after removal of the cartilage of the heads using a specially designed reamer set. We always intend to reconstruct the normal anatomical position of the centre of rotation using the transverse ligament as reference. Vacuum-mixed cement loaded with antibiotics is injected directly from a cement gun and the cement is pressurized by a special pressurizer. After 4-5 minutes of pressurizing a full polyethylene cup is placed in the cement layer and held in position until the cement is completely polymerized in about 9-11 minutes (Figure 1D). The bone impaction grafting technique has been described in detail in the literature.[44-48] Specimen retrieval studies have shown that the layer of impacted bone grafts, at least at the acetabular side, incorporates into normal trabecular bone.[49,50] With the incorporation of these bone grafts a unique and strong construction of the cup, cement, impacted grafts, and pelvic bone is created.

On the femoral side, reconstruction with impacted bone grafts is performed in a similar way during the femoral revision procedure using a specially designed set of instruments. After cleaning and reaming the femoral shaft, segmental defects are reconstructed with thin metal wire meshes. Often reconstruction of the calcar is necessary. A distal femoral plug is inserted with a guide wire attached in the femoral shaft at least 4-5cm below the most distal defect. Over this guide wire a phantom implant is used to impact the morselized bone grafts in the femoral shaft (Figure 4A-B). The bone grafts that are used in the distal femoral shaft are 50% smaller than the ones used in the acetabular reconstruction. The phantom impactor and the intended Exeter implant with its 2mm cement layer are of equal size. At the more proximal part of the femur, larger morselized grafts are used and these are solidly impacted around the phantom with special small impactors creating rotational stability of the final implant (Figure 4C). Finally the femoral implant can be inserted and cemented into the new reconstructed femur.[51,52]

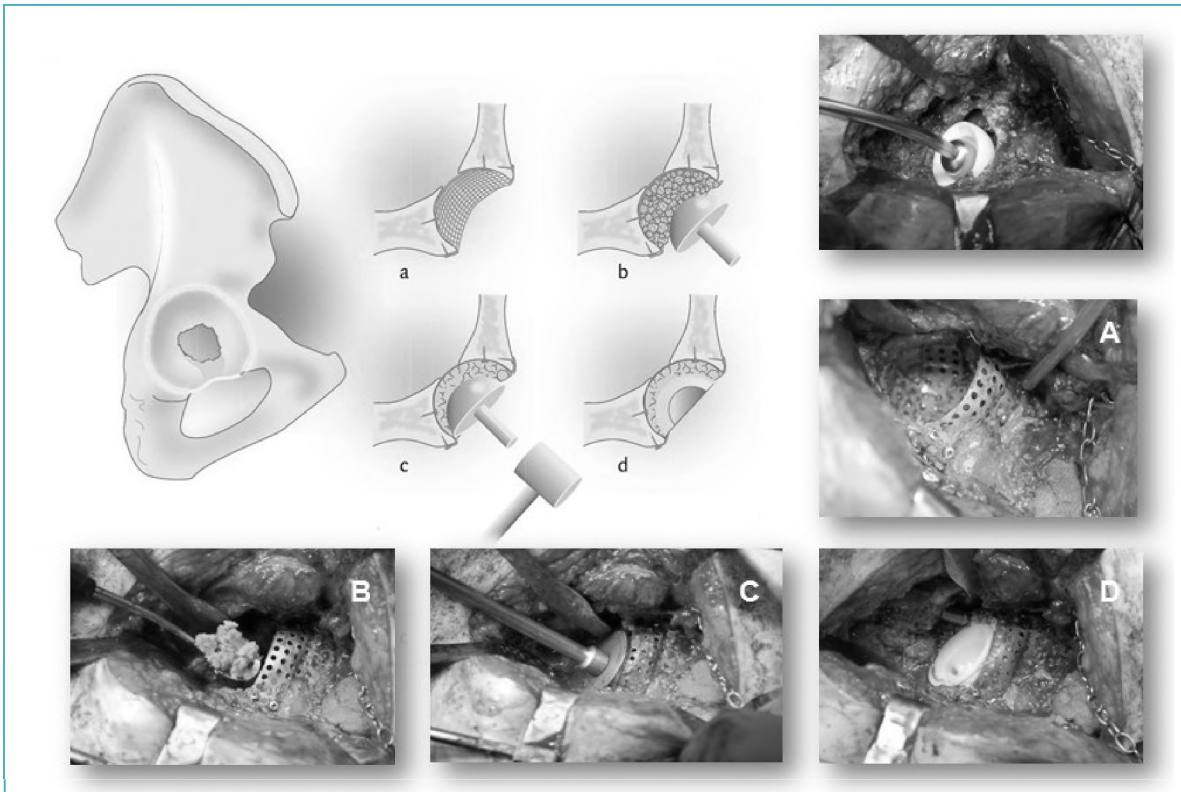


Figure 3A-D. The reconstruction of acetabular defects with bone impaction grafting.
Reconstruction of the defects with wire meshes (A), placing of the morselized bone grafts (B), Impaction of the bone grafts (C), and final result with a cemented polyethylene cup (D).[53]

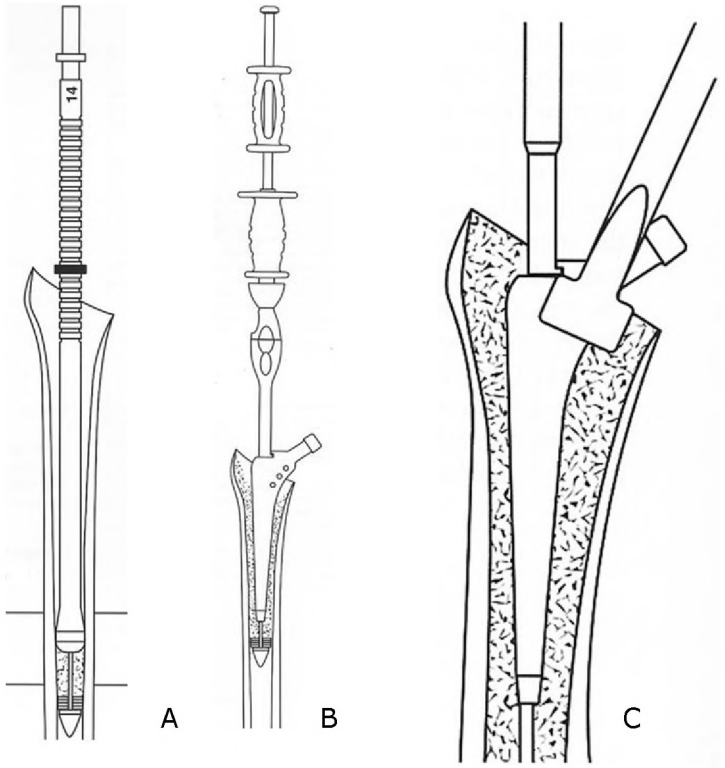


Figure 4A-C. Femoral reconstruction of bone defects with bone impaction grafting.
Reconstruction of the most distal part (A), the phantom in situ for reconstruction of the middle part (B), and reconstruction of the most proximal part with special impactors (C).[52]

Outline of the thesis

The aim of this thesis is to evaluate the hypothesis that the results of current cemented total hip arthroplasty in young patients are still satisfactory. The secondary objective is to evaluate the results of the use of impacted morselized bone grafts in the reconstruction of bone defects in these young patients. The Department of Orthopaedic Surgery of the Radboud University Nijmegen Medical Centre uses only cemented implants in all patients who need a total hip arthroplasty, even the young patients. Currently, there is a clear trend for using uncemented implants in these patients; some countries even abandoned the use of cemented implants in young patients because of the suggested disappointing results of cemented total hip arthroplasties in this population according to scientific and popular literature.

But are these results really disappointing? In order to achieve our goals and provide an answer to this question, several other questions arise and need to be addressed.

First, the results of cemented total hip arthroplasties are compared with the results of uncemented total hip arthroplasties. In **Chapter 2** we describe the results of a literature review about reported studies with a follow-up longer than 10 years to answer the question whether the results of cemented THA in young patients are really that disappointing. With this review we could confirm or invalidate the statement that cemented THA are inferior to uncemented THA.

After evaluating the published results we critically evaluated our own current results. Since 1997 we only use the Exeter stem (Stryker-Howmedica, Newbury, UK) implant. But are the medium-term results of this prosthetic implant in very young patients (under 40 years) worrisome or promising? Do we need to continue our current practise or do we indeed need to, as the literature implies, switch to uncemented stems? These questions are answered in **Chapter 3**.

We use the bone impacting grafting technique in the reconstruction of all acetabular defects. The cups that need reconstruction have acetabular defects and are therefore more difficult and challenging total hip arthroplasties. It could be that the results of these cups are inferior to the results of the cups without bone impaction grafting. Are the results of cemented cups in young patients not good and are the results of reconstructed cups inferior to the cups without a reconstruction? In **Chapter 4** we compare the results of the cups reconstructed with and without bone stock loss and subsequent reconstruction of these defects with bone impaction grafting in patients under the age of 40.

In **Chapter 5** we present an overall outcome of the results of all total hip arthroplasties in the patients under the age of 40. Both cup and stem were assessed and all cemented designs used between 1988 and 2004 were included. Are the overall results of all cemented THA in our young patients comparable to those reported in the literature? Using these criteria, it allows us to present the long-term results of cemented total hip arthroplasties in the very young patients of our population.

After addressing the above mentioned questions we extended our database with the patients operated between the age of 40 and 50 years in **Chapter 6**. Are the results of these patients more like the normal, older total hip arthroplasty population or are their results more comparable to those of the very young population under the age of 40?

What are the long-term results of total hip arthroplasties with an acetabular reconstruction with bone impaction grafting in patients under the age of 50? To answer this question, we evaluated all patients under 50 years operated in our department since the development of this technique at our clinic. We started to use this technique in young

patients in 1979. In **Chapter 7** we describe the results of this reconstruction technique since its development.

Chapter 8 defines a new criterion: the revisability of a prosthesis. Are cemented THA in young patients revisable? In this chapter we describe the long-term results of all total hip arthroplasties in patients under the age of 50 and the short to medium term results of the revisions performed within this population. We would like to emphasize that not only the results of the primary total hip arthroplasty are important but also the results of the revisions of primary total hip arthroplasties in young patients.

Not only should the results of primary total hip arthroplasties be evaluated, but also the results of revision arthroplasty. The question "what the medium and long-term results are of cemented revision total hip arthroplasty in patients under the age of 60?" is answered in **Chapter 9**. Are these results acceptable or should we only use uncemented implants in the revision of failed primary total hip arthroplasty?

Reference list

1. Otten R, Roermund PM, Picavet HSJ. Trends in aantallen knie- en heupartroplastieken. *Ned Tijdschr Geneeskd* 2010;154(20):A1534
2. The National Institute for Public Health and the Environment (RIVM) (Rijksinstituut voor Volksgezondheid en Milieu).
3. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007;370(9597):1508-19.
4. Coventry MB. Lessons learned in 30 years of total hip arthroplasty. *Clin Orthop Relat Res* 1992;274:22-9.
5. Muller ME. Lessons of 30 years of total hip arthroplasty. *Clin Orthop Relat Res* 1992;274:12-21.
6. Bsila RS, Inglis AE, Ranawat CS. Joint replacement surgery in patients under thirty. *J Bone Joint Surg Am* 1976;58(8):1098-104.
7. Chiu KY, Ng TP, Tang WM, Poon KC, Ho WY, Yip D. Charnley total hip arthroplasty in Chinese patients less than 40 years old. *J Arthroplasty* 2001;16(1):92-101.
8. Chmell MJ, Scott RD, Thomas WH, Sledge CB. Total hip arthroplasty with cement for juvenile rheumatoid arthritis. Results at a minimum of ten years in patients less than thirty years old. *J Bone Joint Surg Am* 1997;79(1):44-52.
9. Kim YH, Oh SH, Kim JS. Primary total hip arthroplasty with a second-generation cementless total hip prosthesis in patients younger than fifty years of age. *J Bone Joint Surg Am* 2003;85(1):109-14.
10. McAuley JP, Szuszczewicz ES, Young A, Engh CA, Sr. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-25.
11. Sochart DH, Porter ML. Long-term results of cemented Charnley low-friction arthroplasty in patients aged less than 30 years. *J Arthroplasty* 1998;13(2):123-31.
12. Hartofilakidis G, Karachalios T, Karachalios G. The 20-year outcome of the charnley arthroplasty in younger and older patients. *Clin Orthop Relat Res* 2005;434:177-82.
13. Charnley J. Arthroplasty of the hip. A new operation. *Lancet* 1961;1(7187):1129-32.
14. Murphy JB. Bony lipping of the right acetabular margin and the neck of the femur following a metastatic arthritis. *Arthroplasty of the hip* 1915(4):239.
15. Smith-Petersen MN. Evolution of mould arthroplasty of the hip joint. *J Bone Joint Surg Am* 1948;30(1):59-75.
16. Judet J, Judet R. The use of an artificial femoral head for arthroplasty of the hip joint. *J Bone Joint Surg Br* 1950;32(2):166-73.
17. Moore AT. Metal hip joint; a new self-locking vitallium prosthesis. *South Med J* 1952;45(11):1015-19.
18. McElfresh E. *History of Arthroplasty*: W.B.Saunders Company Philadelphia, 1991.
19. Harris WH. The first 32 years of total hip arthroplasty. One surgeon's perspective. *Clin Orthop Relat Res* 1992;274:6-11.
20. Mulroy RD, Jr., Harris WH. The effect of improved cementing techniques on component loosening in total hip replacement. An 11-year radiographic review. *J Bone Joint Surg Br* 1990;72(5):757-60.
21. Mittelmeier H, Harms J. Treatment of post-traumatic hip joint disease by total replacement with a ceramic endoprosthesis. *Unfallheilkunde* 1979;82(2):67-75.
22. Slooff TJ. A cement syringe. *Acta Orthop Belg* 1969;35(6):1012-4.
23. Slooff TJ. [The use of acrylic cement in orthopedic surgery]. *Z Orthop Ihre Grenzgeb* 1971;109(3):511-21.
24. Huiskes R, Verdonschot N, Nivbrant B. Migration, stem shape, and surface finish in cemented total hip arthroplasty. *Clin Orthop Relat Res* 1998;355:103-12.
25. Scheerlinck T, Casteleyn PP. The design features of cemented femoral hip implants. *J Bone Joint Surg Br* 2006;88(11):1409-18.
26. Shen G. Femoral stem fixation. An engineering interpretation of the long-term outcome of Charnley and Exeter stems. *J Bone Joint Surg Br* 1998;80(5):754-6.
27. Lee AJ, Ling RS. Improved cementing techniques. *Instr Course Lect* 1981;30:407-13.
28. Oh I, Carlson CE, Tomford WW, Harris WH. Improved fixation of the femoral component after total hip replacement using a methacrylate intramedullary plug. *J Bone Joint Surg Am* 1978;60(5):608-13.
29. Burke DW, Gates EI, Harris WH. Centrifugation as a method of improving tensile and fatigue properties of acrylic bone cement. *J Bone Joint Surg Am* 1984;66(8):1265-73.
30. Wixson RL, Lautenschlager EP, Novak MA. Vacuum mixing of acrylic bone cement. *J Arthroplasty* 1987;2(2):141-9.
31. Oh I, Bourne RB, Harris WH. The femoral cement compactor. An improvement in cementing technique in total hip replacement. *J Bone Joint Surg Am* 1983;65(9):1335-8.
32. Bizot P, Banallec L, Sedel L, Nizard R. Alumina-on-alumina total hip prostheses in patients 40 years of age or younger. *Clin Orthop Relat Res* 2000;379:68-76.
33. Duffy GP, Berry DJ, Rowland C, Cabanela ME. Primary uncemented total hip arthroplasty in patients <40 years old: 10- to 14-year results using first-generation proximally porous-coated implants. *J Arthroplasty* 2001;16(8 Suppl 1):140-4.
34. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC, Hardinge K. Long-term results of Charnley low-friction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75(4):616-23.
35. Odent T, Journeau P, Prieur AM, Touzet P, Pouliquen JC, Glorion C. Cementless hip arthroplasty in juvenile idiopathic arthritis. *J Pediatr Orthop* 2005;25(4):465-70.
36. Kobayashi S, Eftekhar NS, Terayama K, Joshi RP. Comparative study of total hip arthroplasty between younger and older patients. *Clin Orthop Relat Res* 1997;339:140-51.
37. Schmalzried TP, Huk OL. Patient factors and wear in total hip arthroplasty. *Clin Orthop Relat Res* 2004;418:94-7.

38. Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *J Arthroplasty* 1998;13(8):890-5.
39. Beaule PE, Dorey FJ, Hoke R, Leduff M, Amstutz HC. The value of patient activity level in the outcome of total hip arthroplasty. *J Arthroplasty* 2006;21(4):547-52.
40. Sechriest VF, 2nd, Kyle RF, Marek DJ, Spates JD, Saleh KJ, Kuskowski M. Activity level in young patients with primary total hip arthroplasty: a 5-year minimum follow-up. *J Arthroplasty* 2007;22(1):39-47.
41. Hastings DE, Parker SM. Protrusio acetabuli in rheumatoid arthritis. *Clin Orthop Relat Res* 1975;108:76-83.
42. McCollum DE, Nunley JA, Harrelson JM. Bone-grafting in total hip replacement for acetabular protrusion. *J Bone Joint Surg Am* 1980;62(7):1065-73.
43. Slooff TJ, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Scan* 1984;55(6):593-6.
44. Schreurs BW, Busch VJ, Welten ML, Verdonschot N, Slooff TJ, Gardeniers JW. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86(11):2385-92.
45. Schreurs BW, Gardeniers JW, Slooff TJ. Acetabular reconstruction with bone impaction grafting: 20 years of experience. *Instr Course Lect* 2001;50:221-8.
46. Schreurs BW, Slooff TJ, Buma P, Verdonschot N. Basic science of bone impaction grafting. *Instr Course Lect* 2001;50:211-20.
47. Slooff TJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Belg* 1986;52(3):324-7.
48. Slooff TJ, Buma P, Schreurs BW, Schimmel JW, Huiskes R, Gardeniers J. Acetabular and femoral reconstruction with impacted graft and cement. *Clin Orthop Relat Res* 1996;324:108-15.
49. Buma P, Lamerigts N, Schreurs BW, Gardeniers J, Versleyen D, Slooff TJ. Impacted graft incorporation after cemented acetabular revision. Histological evaluation in 8 patients. *Acta Orthop Scand* 1996;67(6):536-40.
50. Van der Donk S, Buma P, Slooff TJ, Gardeniers JW, Schreurs BW. Incorporation of morselized bone grafts: a study of 24 acetabular biopsy specimens. *Clin Orthop Relat Res* 2002;396:131-41.
51. Schreurs BW, Arts JJ, Verdonschot N, Buma P, Slooff TJ, Gardeniers JW. Femoral component revision with use of impaction bone-grafting and a cemented polished stem. Surgical technique. *J Bone Joint Surg Am* 2006;88 Suppl 1 prt 2:259-74.
52. Schreurs BW, Arts JJ, Verdonschot N, Buma P, Slooff TJ, Gardeniers JW. Femoral component revision with use of impaction bone-grafting and a cemented polished stem. *J Bone Joint Surg Am* 2005;87(11):2499-507.
53. Busch VJ, Gardeniers JW, Slooff TJ, Veth RP, Schreurs BW. [Favourable long-term results from cemented total hip arthroplasty combined with acetabular bone impaction grafting in patients under the age of 50]. *Ned Tijdschr Geneeskd* 2007;151(35):1935-40.

Chapter 2

Total hip arthroplasties in young patients under 50 years: limited evidence for current trends
A descriptive literature review

D.C.J. de Kam
V.J.J.F. Busch
R.P.H. Veth
B.W. Schreurs

Hip International (Accepted).

Abstract

Background and purpose. We extracted from the literature all reported outcomes of uncemented and cemented total hip arthroplasties implanted in patients younger than 50.

Methods. We searched Medline (1966- 1 January 2009) and PubMed for articles related to total hip arthroplasties in patients under 50 years. Reference lists were evaluated for relevant papers. In addition, we also used the data of the Swedish Hip register.

Results. 109 articles were found related to total hip arthroplasty in patients under 50 years of age, 37 articles had a mean follow-up longer than 10 years. Although uncemented hip implants are widely used in patients under 50 years, there are only 2 reports that fulfil the NICE criteria (follow-up of >10yrs and survival of ≥90%).

Interpretation. It must be concluded that in the current literature about total hip arthroplasty in young patients the current trends still are not supported by survival data in contrast to cemented hips. Additional information about the long-term results of newer implants is essential. In the current literature, most satisfying results are obtained with cemented implants.

Introduction

The total hip replacement is one of the most successful and cost effective interventions of modern medicine [1,2]. The era of modern hip implants started with the development of the cemented total hip arthroplasty as developed by Sir John Charnley (1961). Soon after the introduction of these cemented total hip implants it became clear that the outcome of these cemented hip implants in younger patients was less favourable [3-5].

As a reaction to these disappointing results with cemented hips implants in young patients, surgeons and companies started to develop and use uncemented hip implants in these younger patients. These implants are based on the osseointegration of bone onto or into the outer shell of the implant. Therefore, these implants have a rough or coated outer surface (with hydroxyapatite for example). Within the shell, a polyethylene or ceramic liner as bearing surface is placed. These uncemented hip implants are available in many modifications and these implants are on the market now for more than 25 years. In many countries, these uncemented total hip implants dominate the market and are very frequently used in the younger patients with hip problems requiring a hip replacement. In some countries like the Unites States, cemented implants are hardly ever used in patients under 50 years. Over 90% of all THA inserted in North America are uncemented, while >90% of all THA implanted in Scandinavia and some countries in Europe are cemented: the so-called 'North Atlantic Divide'.

However, especially in young patients, surgeons should be interested in offering hip implants to young patients that will provide long-term success [6]. Most short-term and intermediate-term studies are not helpful in differentiating failing components from components that have long-term success [6].

As a sequence of a discussion about the long-term survival of uncemented and cemented total hip arthroplasties in young patients in 2005 [7,8], we have performed a literature review of all available studies about total hip arthroplasties in patients under the age of 50. The goal of this review was to study the current, updated, clinical evidence that supports the popularity of uncemented total hip prostheses in young patients under 50 years.

Long-term outcome of hip prostheses is in generally defined as the outcome 10 years or more after surgery. For this review we adopted the criteria of the NICE 2003 report for a good long-term outcome of hip prostheses, which is defined as a survival rate of 90 percent or more of the whole implant at 10 years after surgery [9]. We studied and describe the literature of all studies about total hip arthroplasties in patients under the age of 50 with a minimum follow-up of 10 years on average which fulfils the these NICE criteria of ≥90% survival after 10 years. Also, we have performed a statistical analysis of the results of uncemented and cemented outcomes, in studies with a mean follow-up longer than 10 years on average. With this review we would like to open the discussion about evidence based medicine in total arthroplasty in a special and high demanding population: patients under the age of 50.

Methods

A systemic literature review was performed searching Medline and PubMed (1966- 1 January 2009) for articles related to total hip implants in patients less than 50 years. 2 groups of key words were used in combination with each other (group 1: less, 50, fifty, 45, 40, forty, 35, 30, thirty, 25, 20, twenty, or young* and group 2: arthroplast*, hip, acetabul*, femor*, component*, cement*, uncement*, or noncement*). Asterisks were used to expand the search field of a key word. We also searched the reference list of selected papers for relevant other papers.

Inclusion criteria for the review were: primary total hip arthroplasty, age at index surgery <50, and minimum mean follow-up of 10 years. Additional, another inclusion criterion was used (adapted NICE-criteria of survival of ≥90% with endpoint revision for any reason of either component) for the descriptive review. We also included combinations of fixation techniques (multiple techniques). In the so called hybrid total hips uncemented cups are combined with cemented stems, in the reverse hybrid hips

cemented cups are combined with uncemented stems. Exclusion criteria maintained were: studies with only bipolar or resurfacing arthroplasty, hip arthroplasty because of tumours, reports of only one component of a total hip arthroplasty or studies with incomplete data (for example studies only reporting aseptic survival). Revision was defined as the removal or replacement of one or more components of the arthroplasty. With this definition, liner exchanges in uncemented implants were also considered as a revision.

The retrieved articles of the search query were first scanned for relevance and subject. The remaining articles were evaluated on number of patients and arthroplasties, age of the population (mean and range), duration of follow-up, type of implant(s) used, surgical techniques used (cemented, uncemented, hybrid or multiple techniques) and survival outcome. In case the survival was only described in a graph, the 10 year survival was estimated from the graph. Authors of articles with satisfying long-term (>10 yrs) were contacted if the results at 10 years were not reported or no survival graph was present, to obtain the 10 years results of these studies. The articles were reviewed by two independent reviewers and both extracted data from the articles.

For statistical analysis, update studies of previous reports were excluded from the statistical analysis in order to prevent inclusion of the same results more than 1 time, and only studies with endpoint revision for any reason were included. A Thunnel plot was used to outline any publication bias and we used a weighted regression analysis for testing significant differences in survival between the different fixation types, correcting for (if reported): population size, 95% confidence intervals, number of patients remaining after 10 years.

Results

Papers

The search query resulted in 2999 hits and after evaluation and selection 109 studies reported survival results in patients under the age of 50. Of these 109 studies, 37 studies had a mean survival of >10 years, and 15 articles comply with the criteria of a reported survival of ≥90% after a mean follow-up of >10 years. Figure 1 shows the flowchart of the articles included in the search.

Table 1 shows the articles of total hip arthroplasty in patients under the age of 50, with a minimum average follow-up of 10 years, and with a survival of ≥90% with endpoint revision for any reason of either component. Of the 15 remaining studies, 1 was about uncemented implants, 13 were about cemented total hip arthroplasties and 1 reported the use of multiple techniques (uncemented and hybrid implant fixation). No prospective comparable studies were available which fulfils the search criteria.

Uncemented total hip implants

Only one study about uncemented implants does fulfil the NICE criteria. In the study of McCullough et al. [10] a survival of 90% at 10 years is reported, with the use of a custom-made hydroxyapatite-coated femoral implant. They studied 42 hips in 25 patients with inflammatory polyarthropathy. The mean age in this study was 21 (11-35) years. Patients aged less than 16 years had the highest risk of failure of the femoral component (28.5% at 10 years). However, in normal standard orthopaedic practise it is very unusual to implant custom made prostheses.

Cemented total hip implants

Boeree and Bannister [11] reported the outcome of 46 cemented total hip implants in 34 patients under 50 years. The average age was 38 (24-49) years. Diagnoses were a wide range of hip diseases, however most rheumatoid arthritis (12 hips) and congenital hip dysplasia (11 hips). The survival rate was 90% at 10 years, just fulfilling the NICE criterion.

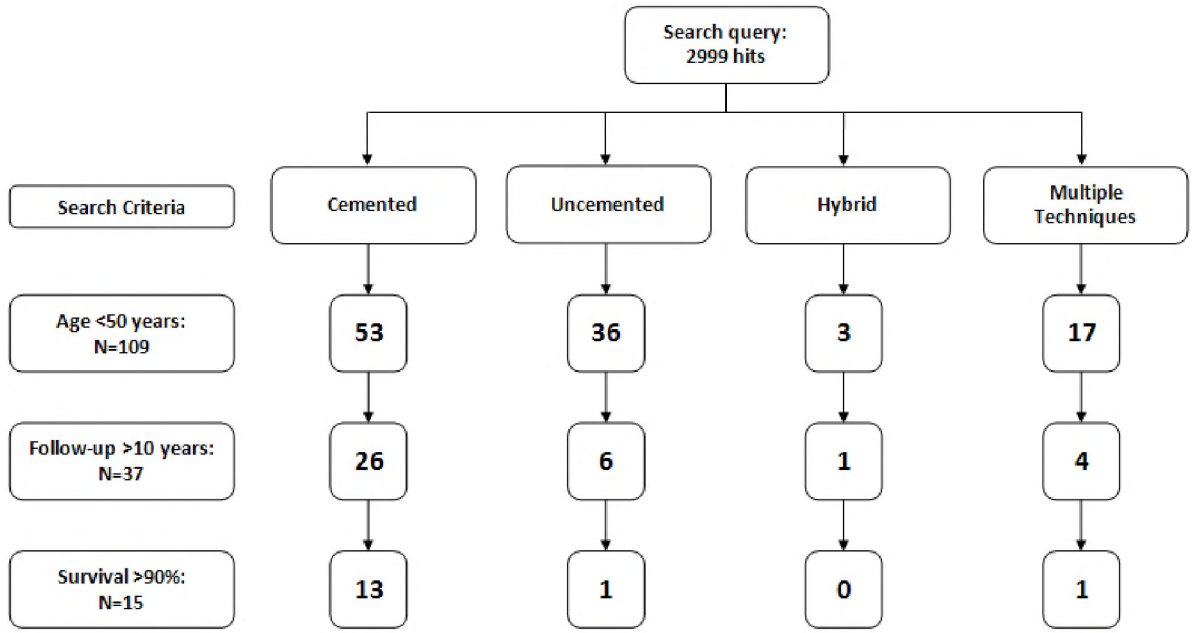


Figure 1. Results of the search query and selection after the use of the search criteria.

Emery et al. [12] reported on 57 hips implanted in 46 patients under the age of 50 years. The average age was 41 (17 to 49) years and the average follow-up was 13 years. Most frequent diagnoses were primary osteoarthritis in 23 hips, rheumatoid arthritis in 12 hips and congenital hip dysplasia in 10 hips. The survival of the implant was 90% at 10 years. After 10 years there is a large decline in survival with a survival of 68% at 15 years.

Joshi et al. [13] reported on the long-term outcome of 218 cemented total hip arthroplasties in 141 patients under 40 years (mean 32, range 16-40 years). Indication for the hip implants was rheumatoid arthritis in 74 hips, congenital hip dysplasia in 47 hips, ankylosing spondylitis in 41 hips and 56 had osteoarthritis. The survival of the implant with endpoint revision of any part of the prostheses was 93% at 10 years and 75% at 20 years.

Keener et al. [14] reported the 25 years results after 93 cemented total hip arthroplasty in 69 patients less than 50 years. The average age was 42 (18-49) years. Diagnoses for the hip implant were multiple, but most congenital hip dysplasia (28 hips), primary osteoarthrosis (11 hips) and posttraumatic arthrosis (11 hips). Unfortunately, the survival rate at 10 years was not reported. Analyzing the reported survival curves, the 10 years survival fulfils the 90% criterion. The survival rate with endpoint revision for any reason was reported as 69% at 25 years and 60% at 30 years. The evaluated cohort in the study of Keener et al. was an update of the same cohort first reported by Callaghan et al. [15] and Sullivan et al. [16], all showing the same results after 10 years.

In the study of Kerboull et al. the results of 287 Charnley-Kerboull implants were reported [17]. The 222 patients had a mean age of 40 (15-50) years and were followed up to 25 years. They found no significant differences in the survival in patients under and above the age of 40. The only predictive factor of loosening they found was a wear rate higher than 0.1 mm per year.

Kobayashi et al. [18] reported the outcome of 66 cemented total hips in patients under 50 years. The average age was 37 (18-50) years. Most frequent diagnoses were rheumatoid arthritis (18 hips) and osteoarthrosis. Although they did report the survival of the cup and the stem separately, at 10 years the cup survival for any reason was 98% at 10 years and the stem survival was not reported at 10 years but at 16 years to be 96%. Even in case these cup and stems revisions were done separately in patients, and even including one revision for septic loosening who was excluded by the authors, the 90%

Table 1. Overview of the studies who do fulfil the adapted NICE criteria after a mean follow-up of 10 years.

Study	No. Hips	No. Patients	Mean age (range)	Follow-up (range)	Type of Implant	Survival THP endpoint any reason (95% C.I.)
Uncemented						
McCullough et al.(2006)	42	25	21 (11-35)	11.2 (8-13)	HA CAD-CAM	90% (78-97%)
Cemented						
Boeree et al. (1993)	46	34	38 (24-49)	12 (10-18)	Charnley & Howse	90% (n/a)
Callaghan et al.(1998)*	93	69	42 (18-49)	20 (5-25)	Charnley	90% (84-96%)
Emery et al.(1997)	57	46	41 (17-49)	13 (0.3-21)	Stanmore	90.8% (n/a)
Joshi et al.(1993)	218	141	32 (16-40)	16 (10-24)	Charnley	93% (SE 1.8)
Keener et al.(2003)*	93	69	42 (18-49)	25.8 (25-n/a)†	Charnley	90% (84-96%)
Kerboull et al.(2004)	287	222	40.1 (15-50)	14.5 (0.5-25)	Charnley-Kerboull	95.9% (92.8-98.4%)
Kobayashi et al.(1997)	66	n/a	37 (18-50)	14 (10-20)†	Charnley	98.2% (n/a)
Lewthwaite et al.(2008)	123	101	42 (n/a-50)	12.5 (10-17)	Exeter	94.4% (89-98%)
Sochart et al.(1997a)	226	161	31.7 (17-39)	19.7 (2-30)	Charnley	93% (90-96%)
Sochart et al.(1997b)	43	24	28 (19-39)	22.7 (0.1-30.3)	Charnley	91% (82-100%)
Sullivan et al.(1994)*	89	67	42 (18-49)	18 (16-22)	Charnley	90% (84-96%)
Wroblewski et al. (2004)	190	173	41 (18-50)	15.6 (1-31)	Charnley	94.9% (89.7-100%)
Wroblweski et al. (2007)	292	195	38 (12-50)	15 (1-36)	Charnley	93% (90-96%)
Hybrid						
None						
Multiple techniques						
Singh et al.(2004)	38	33	42 (22-49)	10 (5.3-14.2)	HA JRI Furlong	Hybrid: 100% (78-100%) Uncemented: 96% (75-100%)

*: Updates of same cohort; †: deceased excluded HA: Hydroxyapatite-coated

survival at 10 years criterion is fulfilled. Revisions rates were highest in the patients with rheumatoid arthritis.

Lewthwaite et al. [19] present the results of the cemented Exeter hip in patients under the age of 50. They found a survival of 94.4% after 10 years, after evaluation of 123 hips in 101 patients. A rather significant part (44 patients) of their original population was excluded of the study. In 10 years, 6 hips were revised and 1 periprosthetic fracture occurred but the original components retained.

Sochart and Porter [20] reported the long-term results of 43 total hip replacements in 24 young patients (mean age 28 years) who had ankylosing spondylitis at 18 to 30 years after surgery. Survival of the total hip replacement was reported at 91% at 10 years, 73% at 20 years and 70% at 30 years.

In another report by Sochart and Porter they reported the long-term results of 226 cemented total hip replacements in 161 patients in patients under 40 years [21]. The average age was 32 (17-39) years. Indication for the total hip was congenital dislocation of the hip in 60 hips, primary osteoarthrosis in 66 hips and rheumatoid arthritis in 100 hips. Survival of the total hip replacement was 91% at 10 years, 67% at 20 years and 65% at 25 years. Total hip implanted in patients with primary osteoarthritis had the worst results, 86% survival at 10 years.

Wroblewski, Siney and Fleming report in two papers, probably based on one population under 50, a survival fulfilling the NICE-criteria. In the first paper a subgroup of 190 hips in 173 patients with low-wear rates achieve a survival of 95% at 10 years [22]. The second paper with 292 hips in 195 patients with inflammatory arthrosis shows a survival of 93% after 10 years [23]. They concluded that wear and aseptic cup loosening are the main long-term problems.

Hybrid total hip implants
There were no studies available with only hybrid implanting techniques that fulfilled the criteria

Multiple implantation techniques
Singh et al. [24] reported excellent survival rates in a population consisting of 38 hips in 33 patients. All patients had an uncemented JRI Furlong hydroxyapatite coated stem, the first 14 hips received a cemented cup and the remaining 24 a screw-fit hydroxyapatite coated cup. The mean age was 42 (22-49) years with an average follow-up of 10 (5.3-14.2) years. The reversed hybrid arthroplasties showed a survival of 100% at 10 years and the total uncemented arthroplasties 96% at 10 years.

Scandinavian Hip Registers
The Swedish register is the only register, which presents data of total hip arthroplasties inserted in patients younger than 50 years. The last available annual report of the Swedish National Hip Arthroplasty Register is from 2007 [25]. In this report, the survival of the cohort of all cemented and the cohort of all uncemented implants inserted in patients younger than 50 years in Sweden in the period 1992-2007 is reported using survival analyses for endpoint revision for any reason. At 10 years, both the cemented and the uncemented survival curves are lower than 90%, so the NICE criteria are not passed. At 16 years after implantation the survival of the cemented hip is for man 74.7% (95%C.I. 67.4-82.1) based on 1478 included hip arthroplasties and 72.5% (95%C.I. 66.4-78.7) for women based on 1883 hips. The outcome of the uncemented implants however, is clearly worse. At 16 years after implantation the survival of the uncemented hip is for man 57.4% (95%C.I. 47.5-67.4) based on 1371 included hip arthroplasties and for women 54.3% (95%C.I. 46.8-61.7) based on 1347 hips. Unfortunately, no detailed reports on individual implants are available to specify the results of the newer uncemented implants.

Statistical analysis
For statistical analysis, first a Thunnel plot of all the studies with a follow-up longer than 10 years with any survival rate was made (n=37) (Figure 2). The log of the number of patients included in the studies was related to the overall outcome (survival) of the THA with endpoint revision for any reason of either component. 37 studies with were included in the forest plot and the different fixation types were noted separately. No specific outliners were observed and therefore no publication bias is noticed.

Articles which were updates of other studies were not included in this statistical analysis (2 studies about cemented implants), 1 study about cemented implants did not report survival with endpoint revision for any reason and was excluded, and Singh et al. [24] reported in their study with multiple techniques the results of uncemented implants separately and therefore these results could be included. Finally, twenty-three studies with 3759 patients in total discussed the outcome of cemented THA (26 studies minus 2 updates and 1 incomplete report), and 7 studies about uncemented implants with in total 372 patients were included (6 studies plus the results of the uncemented implants of Singh et al.). A weighted regression analysis showed a significant better survival of the cemented THA in contrast to the uncemented THA: 87.7% (95%CI: 83.2-92.2%) versus 75.2% (95%CI: 66.3-84.1%) (difference: 13.7% (95%CI: 9.7-17.7%); $p < 0.001$).

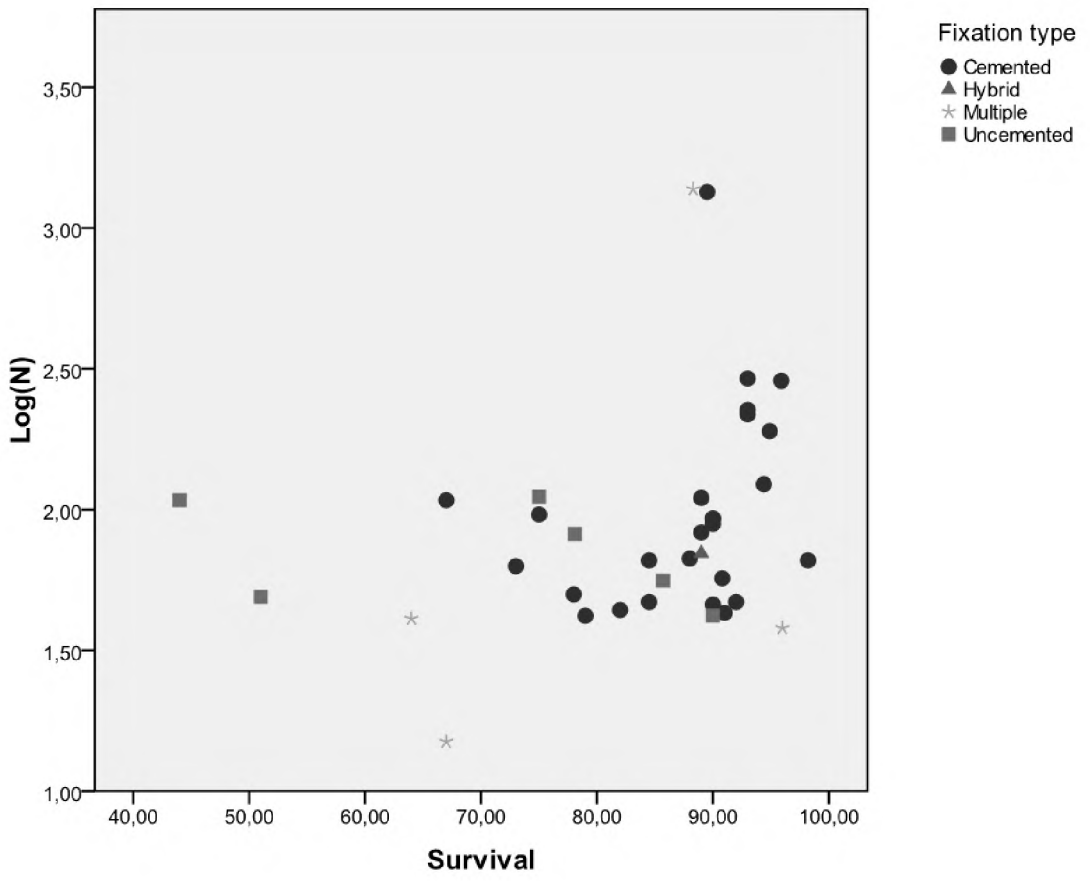


Figure 2. Forest plot of the studies with a follow-up of more than 10 years.

Discussion

Although uncemented implants are very popular in patients under 50 years of age and in some countries are exclusively used in these patients, there is limited clinical evidence that these implants really have improved the outcome for these patients at 10 years or more after surgery, based on the results reported.

Confusing in studying outcome studies of uncemented hips is the fact that revision of a failed insert of an uncemented metal shell is not always reported as a revision. Most uncemented cup implants exist of a metal outer shell and an insert of polyethylene. In many of these uncemented designs, this plastic inserts wears out and has to be replaced. If the metal shell is still well fixed in the bone, surgeons have the option to change only the insert. However, not all studies report this exchange as a revision, which can make a dramatic difference in the reported outcome (e.g. cup survival with endpoint revision of the metal shell at 14 years is 70%, however including liner exchange 54%(Capello et al. [26])).We agree with the Scandinavian Hip Registers that these liner exchanges should be included in the reported revision survival rates. The other confusing fact, both for surgeons but also for patients who are reviewing the literature using the internet, is that many outcome studies, uncemented and cemented, are reported on only the cup or only the stem survival. Although for scientific reasons focussing on one part of the implant is correct, it would be really an improvement to make the literature more clear to present in all abstracts of primary hip implants always the survival with endpoint revision of either component. Of course, patients will benefit only of a total hip implant if both components survive well. A confounding factor in our conclusions and statistical analysis could be that the underlying diagnoses of the hip disease and the activity level of these patients are not comparable between cemented and uncemented studies. The used

studies were very heterogenic. Patients with primary osteoarthritis do worse, relative to patients with rheumatic diseases or other underlying hip diseases. However, as in many countries in all young patients uncemented implants are used, it is unlikely that this will bias the conclusion. Other limitations are the fact that the long-term results of the newer generation uncemented implants are not published (yet) and that the results of studies with bad results are frequently not published.

In the review we found 9 studies about uncemented hips that had a minimum mean follow-up of 10 years [10,26-33]. However, only one met the NICE criteria, but this study is about custom made prosthesis in low demanding patients. Two important studies that did not fulfil the inclusion criteria should be discussed. Kim et al. reported a series of 118 hips in 80 patients at a mean follow-up of 9.8 years [34]. Therefore this study was not included, however this study shows an excellent survival of an uncemented hip with a survival rate of 99%. These results are very promising and will fulfil the NICE criteria in the future. A problem observed in this study was the very high rate of polyethylene wear. The other report that should be discussed is the study of McAuley et al. [6]. This was not included initially because, due to a different method of reporting, the average follow-up was only 6.9 years. In the study they report a calculated survival rate of 89% at 10 years, approaching the NICE criteria. This important study is the largest one available on 561 uncemented hips in 488 young patients with the longest follow-up. The mean age of was 40 years (16-50 years). The main indications were osteoarthritis (249 hips) and osteonecrosis (111 hips). The survival rate at 15 years in their cohort was 60% with endpoint revision for any reason.

A good survival rate of >90% after a mean of 10 years follow-up is not a guarantee for good very long-term survival. An example is the study of Emery et al. [12]. After 10 years their study showed a result of 90%, just fulfilling the criteria. But after 15 years their survival was 68%, a decrease of 22% in 5 years.

Because cemented total hip implants were already long in use before the implantation of contemporary uncemented hip implants started, long-term reports on cemented hips exceeds the reported survival of uncemented implants. Survival data of cemented hips with endpoint any revision have been reported of 60% after 30 years (Keener et al. [14]), 75% after 20 years (Joshi et al. [13]), again 75% after 20 years (Devitt et al. [35]) and 73% at 20 years (Sochart and Porter [20,21]). These long-term survival data are superior to the longest report available of uncemented hips which has an endpoint revision for any reason at 15 years is 60% (McAuley et al. [6]). Although uncemented implants are use over 25 years, most first generation implants are abandoned. Modern uncemented implants seem to have a better survival, but they need to prove their value on the long-term follow-up. There are studies about the 2nd and 3rd generation uncemented implants with good short term results, like Delaunay et al. [36]. After a mean follow-up of 7.3 years they had a survival of 100%. Another example is the study of Kennedy et al. [37], they found a survival of 94% after 5 years, with a mean follow-up of 7.5 years. Therefore new or updated reports of newer uncemented implants in young patients are necessary to validate the use of uncemented implants in these patients. The new generation uncemented implants show promising short and mid-term survival rates. We hope we can give an update over 5 years including the long-term reports of these implants.

The Swedish hip register confirms the unsatisfying outcome of all arthroplasties in patients under 50 years. However, the reported survival curve of the uncemented implants is again inferior to the reported outcome of the cemented implants. These outcomes of these large cohorts of patients may be biased because older implants with inferior outcome may overshadow better results of some prostheses. In the Swedish report, no detailed information about individual implants is available for young patients.

The last few years there are other alternative bearing types available. The first reports of cross-linked polyethylene, ceramic bearing and metal bearings seem to be promising

in better survival because of less wear in THA patients. Probably these alternate bearings will make a difference in long-term survival in the future.

In conclusion, the outcome of both cemented and uncemented prosthesis in young patients is still disappointing. Most literature that does fulfil the criteria of a survival of ≥90% after 10 years are based on cemented implants. Long-term reports of uncemented (first generation) implants are available, but they do not meet the criteria with the exception of 2 studies. Additional reports about the long-term results of newer uncemented implants are necessary to support their use in young patients.

Acknowledgement
We would like to acknowledge Jan Hendriks, PhD for his support in the statistical analysis and Gerjon Hannink for reviewing the manuscript.

References

1. Laupacis A, Bourne R, Rorabeck C, Feeny D, Wong C, Tugwell P. The effect of elective total hip replacement on health-related quality of life. J Bone Joint Surg Am 1993;75(11):1619-1626.
2. Wiklund I, Romanus B. A comparison of quality of life before and after arthroplasty in patients who had arthrosis of the hip joint. J Bone Joint Surg Am 1991;73(5):765-769.
3. Chandler HP, Reineck FT, Wixson RL, McCarthy JC. Total hip replacement in patients younger than thirty years old. A five-year follow-up study. J Bone Joint Surg Am 1981;63(9):1426-1434.
4. Dorr LD, Takei GK, Conaty JP. Total hip arthroplasties in patients less than forty-five years old. J Bone Joint Surg Am 1983;65(4):474-479.
5. Sharp DJ, Porter KM. The Charnley total hip arthroplasty in patients under age 40. Clin Orthop Relat Res 1985;201:51-56.
6. McAuley JP, Szuszczewicz ES, Young A, Engh CA, Sr. Total hip arthroplasty in patients 50 years and younger. Clin Orthop Relat Res 2004;418:119-125.
7. Schreurs BW, Gardeniers JWM. Total hip arthroplasty for primary osteoarthritis in younger patients in the Finnish arthroplasty register. Correspondence. Acta Orthop 2005;76(4): 604-607.
8. Schreurs BW, Gardeniers JWM. Second letter to the Editor concerning "Total hip arthroplasty for primary osteoarthritis in younger patients in the Finnish arthroplasty register" by Eskelinen et al., Acta Orthop 2005;76:28-41, 604-607. Correspondence. Acta Orthop 2006; 77 (2): 337-41.
9. Guidance on the selection of prostheses for primary total hip replacement. NICE 2003.
10. McCullough CJ, Remedios D, Tytherleigh-Strong G, Hua J, Walker PS. The use of hydroxyapatite-coated CAD-CAM femoral components in adolescents and young adults with inflammatory polyarthropathy: ten-year results. J Bone Joint Surg Br 2006;88(7):860-864.
11. Boeree NR, Bannister GC. Cemented total hip arthroplasty in patients younger than 50 years of age. Ten- to 18-year results. Clin Orthop Relat Res 1993;287:153-159.
12. Emery DF, Clarke HJ, Grover ML. Stanmore total hip replacement in younger patients: review of a group of patients under 50 years of age at operation. J Bone Joint Surg Br 1997;79(2):240-246.
13. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC, Hardinge K. Long-term results of Charnley low-friction arthroplasty in young patients. J Bone Joint Surg Br 1993;75(4):616-623.
14. Keener JD, Callaghan JJ, Goetz DD, Pederson DR, Sullivan PM, Johnston RC. Twenty-five-year results after Charnley total hip arthroplasty in patients less than fifty years old: a concise follow-up of a previous report. J Bone Joint Surg Am 2003;85(6):1066-1072.
15. Callaghan JJ, Forest EE, Olejniczak JP, Goetz DD, Johnston RC. Charnley total hip arthroplasty in patients less than fifty years old. A twenty to twenty-five-year follow-up note. J Bone Joint Surg Am 1998;80(5):704-714.
16. Sullivan PM, MacKenzie JR, Callaghan JJ, Johnston RC. Total hip arthroplasty with cement in patients who are less than fifty years old. A sixteen to twenty-two-year follow-up study. J Bone Joint Surg Am 1994;76(6):863-869.
17. Kerboull L, Hamadouche M, Courpied JP, Kerboull M. Long-term results of Charnley-Kerboull hip arthroplasty in patients younger than 50 years. Clin Orthop Relat Res 2004;418:112-118.
18. Kobayashi S, Eftekhar NS, Terayama K, Joshi RP. Comparative study of total hip arthroplasty between younger and older patients. Clin Orthop Relat Res 1997;339:140-151.
19. Lewthwaite SC, Squires B, Gie GA, Timperley AJ, Ling RS. The Exeter Universal hip in patients 50 years or younger at 10-17 years' followup. Clin Orthop Relat Res 2008;466(2):324-331.
20. Sochart DH, Porter ML. The long-term results of Charnley low-friction arthroplasty in young patients who have congenital dislocation, degenerative osteoarthrosis, or rheumatoid arthritis. J Bone Joint Surg Am 1997;79(11):1599-1617.
21. Sochart DH, Porter ML. Long-term results of total hip replacement in young patients who had ankylosing spondylitis. Eighteen to thirty-year results with survivorship analysis. J Bone Joint Surg Am 1997;79(8):1181-1189.
22. Wroblewski BM, Siney PD, Fleming PA. Wear of the cup in the Charnley LFA in the young patient. J Bone Joint Surg Br 2004;86(4):498-503.
23. Wroblewski BM, Siney PD, Fleming PA. Charnley low-frictional torque arthroplasty in young rheumatoid and juvenile rheumatoid arthritis: 292 hips followed for an average of 15 years. Acta Orthop 2007;78(2):206-210.
24. Singh S, Trikha SP, Edge AJ. Hydroxyapatite ceramic-coated femoral stems in young patients. A prospective ten-year study. J Bone Joint Surg Br 2004;86(8):1118-1123.
25. Annual report 2007 of the Swedish National Hip Arthroplasty register. http://www.jru.orthop.gu.se/. Available from: URL:http://www.jru.orthop.gu.se/. (last checked 8-11-2010)
26. Capello WN, D'Antonio JA, Feinberg JR, Manley MT. Ten-year results with hydroxyapatite-coated total hip femoral components in patients less than fifty years old. A concise follow-up of a previous report. J Bone Joint Surg Am 2003;85(5):885-889.
27. Crowther JD, Lachiewicz PF. Survival and polyethylene wear of porous-coated acetabular components in patients less than fifty years old: results at nine to fourteen years. J Bone Joint Surg Am 2002;84(5):729-735.
28. Duffy GP, Berry DJ, Rowland C, Cabanela ME. Primary uncemented total hip arthroplasty in patients <40 years old: 10- to 14-year results using first-generation proximally porous-coated implants. J Arthroplasty 2001;16(8 Suppl 1):140-144.
29. Kim SY, Kyung HS, Ihn JC, Cho MR, Koo KH, Kim CY. Cementless Metasul metal-on-metal total hip arthroplasty in patients less than fifty years old. J Bone Joint Surg Am 2004;86(11):2475-2481.

30. McLaughlin JR, Lee KR. Total hip arthroplasty in young patients. 8- to 13-year results using an uncemented stem. Clin Orthop Relat Res 2000;373:153-163.
31. Peters CL, Beck M, Dunn HK. Total hip arthroplasty in young adults after failed triple innominate osteotomy. J Arthroplasty 2001;16(2):188-195.
32. Schneider W, Knahr K. Total hip replacement in younger patients: survival rate after avascular necrosis of the femoral head. Acta Orthop 2004;75(2):142-146.
33. Wangen H, Lereim P, Holm I, Gunderson R, Reikeras O. Hip arthroplasty in patients younger than 30 years: excellent ten to 16-year follow-up results with a HA-coated stem. Int Orthop 2008;32(2):203-208.
34. Kim YH, Oh SH, Kim JS. Primary total hip arthroplasty with a second-generation cementless total hip prosthesis in patients younger than fifty years of age. J Bone Joint Surg Am 2003;85(1):109-114.
35. Devitt A, O'Sullivan T, Quinlan W. 16- to 25-year follow-up study of cemented arthroplasty of the hip in patients aged 50 years or younger. J Arthroplasty 1997;12(5):479-489.
36. DeLaunay CP, Bonnomet F, Clavert P, Laffarque P, Migaud H. THA using metol-on-metal articulation in active patients younger than 50 years. Clin Orthop Relat Res 2008;466;340-346.
37. Kennedy JG, O'Loughlin PF, Harty JA, Casey K, Zurakowski D, Quinlan WB. Evaluation of Hylamer-zirconia hip arthroplasty in patients less than 50 years of age. Acta Orthop Belg 2008;74:461-471.


3

Chapter 3

The medium-term results of the cemented Exeter femoral component in patients under 40 years of age

D.C.J. de Kam
R.L.W.A. Klarenbeek
J.W.M. Gardeniers
R.P.H. Veth
B.W. Schreurs

Journal of Bone and Joint Surgery Br 2008;90:1417-21.

Abstract

We evaluated the outcome of 104 consecutive primary cemented Exeter femoral components in 78 patients (34 men, 44 women) under the age of 40 years who underwent total hip replacement between October 1993 and May 2004. The mean age at operation was 31 years (16 to 39). No hip was lost to follow-up, but three patients (four hips) died. None of the deaths were related to the surgery.

At a mean follow-up of 6.2 years (2 to 13), three femoral components had been revised for septic loosening. Using Kaplan-Meier survival analysis, the seven-year survival of the component with revision for any reason as the endpoint was 95.8% (95% confidence interval 86.67 to 98.7). The seven-year survival with aseptic femoral loosening as the endpoint was 100% (95% confidence interval 100).

The cemented Exeter femoral component in patients under the age of 40 shows promising medium-term results. As it is available in a wide range of sizes and offsets, we could address all types of anatomical variation in this series without the need for custom made components.

Introduction

The Exeter cemented femoral component developed in 1969 and was first implanted in November 1970.[1] Since then there have been two minor changes in its design, two changes to the alloy and two to the surface finish, resulting, in 1988, in the production of the Exeter Universal femoral component.[1] This retains its original double tapered design and has a highly polished surface finish. Outcome studies of the Exeter prosthesis have been published for older patient populations,[1,2] but the outcome in younger patients has not been published to date.

In this study we evaluated the clinical and radiological outcome of the Exeter Universal femoral component in 78 patients (104 hips) who were under the age of 40 years at the time of surgery.

Patients and Methods

Between October 1993 and May 2004 we inserted 104 primary cemented Exeter Universal femoral components (Stryker Howmedica, Newbury, United Kingdom) in 78 consecutive patients all of whom were under 40 years old at the time of surgery. All diagnoses were included and no patients were excluded. A cemented acetabular component was used in each case. Many patients in this age group have secondary osteoarthritis due to developmental dysplasia of the hip, inflammatory arthropathy, or avascular necrosis with loss of bone stock. We reconstructed the acetabulum with wire mesh, to contain sequential bone defects, and impaction bone grafting.[3-5]

There were 34 men (44%) and 44 women (56%), of whom 26 underwent a bilateral procedure. In total, 50 femoral components were implanted on the left side and 54 on the right. The mean age at the time of surgery was 31 years (16 to 39).

All patients included in this retrospective review were followed up on a regular basis. During follow-up, three patients (four stems) died, at 4.4, 5.3, 6.9 and 8.5 post-operative years respectively, from causes unrelated to the surgery. None had required revision. All patients were followed for a minimum of two years, and no patient was lost to follow-up. The mean follow-up was 6.2 years (2 to 12.8).

The primary diagnosis was developmental dysplasia in 30 hips, rheumatoid arthritis in 13 and corticosteroid-induced avascular necrosis in 23. Five hips were replaced for idiopathic avascular necrosis, five for Perthes' disease, and five for post-traumatic arthritis. Four hips were replaced for slipped capital femoral epiphysis and four for Morquio's disease. A further 15 hips were replaced for a variety of other diagnoses.

The majority of the operations (94 hips; 90%) were performed by or under the supervision of the two senior faculty surgeons (JWMG, BWS). In each case, a posterolateral approach was used without a trochanteric osteotomy. However, in one procedure a planned Sugioka osteotomy[6] was converted to a total hip replacement (THR) and a trochanteric osteotomy had already been performed. In one other case an additional anterior approach was needed because of ankylosis of the hip. A total of 57 hips had undergone surgery before THR, the number of previous operations ranged from one to eight.

All femoral components were inserted using a third generation cementing technique comprising bone lavage, a distal intramedullary plug and cement pressurisation. Simplex bone cement (Stryker-Howmedica) loaded with antibiotics was used in each case. Immediately before operation each patient received 2 g of cefazolin intravenously. Thromboprophylaxis in the form of low molecular weight heparin was given post-operatively. Non-steroidal antiinflammatory drugs (NSAIDs) were used for seven days post-operatively to prevent heterotopic ossification. When NSAIDs were contraindicated (in four patients), one dose of 7 Gy radiotherapy was given post-operatively.

Patients without bone grafts were mobilised under the supervision of a physiotherapist one or two days after surgery using two crutches. Full weight-bearing was allowed after six weeks. This protocol was adapted for patients who had an acetabular reconstruction depending on the type and extent of the reconstruction.

Routine follow-up was scheduled after six weeks, six, nine and 12 months, and yearly

or biennially thereafter. Clinical evaluation was performed using the Harris hip score (HHS),[7] the Oxford hip score (OHS),[8] visual analogue scales (VAS) for pain at rest and during physical activity on a scale from 0 (no pain) to 100 (unbearable pain), and a VAS for satisfaction on a scale from 0 (not satisfied at all) to 100 (complete satisfaction). The anteroposterior pelvic and lateral hip radiographs of all femoral components were analysed on a consensus basis by two investigators (DCJDK and BWS). Radiological evaluation included an assessment of loosening of the component, its position, osteolysis, rounding-off at the calcar, migration, heterotopic ossification, cortical hypertrophy and/or atrophy and cement fractures. Radiolucent lines and osteolysis were recorded in accordance with the 14 femoral zones described by Gruen, McNiece and Amstutz.[9] A valgus or varus position of the femoral component was evaluated if it lay within 3° of the femoral axis. Loosening was analysed using the criteria described by Harris, McCarthy and O'Neill.[10] In the event of such loosening, we categorised the mode of failure as described by Gruen et al.[9] Subsidence of 2 mm or more was registered as abnormal, as described by Loudon and Older.[11] Heterotopic ossification was defined according to the system of Brooker et al.[12] We defined revision as the removal and/or replacement of the component for any reason. Kaplan-Meier survival analysis was performed for all hips to calculate the cumulative survival with 95% confidence intervals (CI). The survival analysis was performed for four different endpoints: revision of the femoral component for any reason, revision for any reason excluding infection, revision for aseptic loosening, and radiological signs of loosening.

Results

The mean operating time was 151 minutes (65 to 285). There were two intra-operative complications related to implantation of the femoral component. In one femur a hoop stem crack occurred during broaching. This was recognised intra-operatively and treated by cerclage wiring. A technical failure of the implantation technique was seen in one case. The component jammed during insertion, and its removal with some recementing was necessary for proper implantation. Post-operative rehabilitation was uneventful in both cases.

Functional outcome

The mean pre-operative HHS was 51 points (15 to 77) and improved to a mean of 89 points (55 to 100) at final follow-up. The mean OHS improved from 39 points (28 to 52) to 19 points (12 to 45), where the best available score is 12 and 60 the worst. The mean postoperative VAS for pain at rest was 7 points (0 to 75). The mean post-operative VAS score for pain during physical activity was 19 points (0 to 90). The mean VAS for overall satisfaction was 87 points (20 to 100). One patient with secondary osteoarthritis after an acetabular fracture had persistent pain after THR. In the absence of evidence of failure of fixation or infection, this patient was referred for pain management.

Revisions

Three femoral components (3%) were revised, because of septic loosening at 2.2, 3.4 and 6.1 years. The infecting organisms were *Pseudomonas aeruginosa* in one hip and *Staphylococcus epidermidis* in two. In one infected hip, revised after 2.2 years the infection was related to the surgery. The indication for this THR was an infected non-union of a Sugioka osteotomy. The other two infected hips presented as an acute infection in patients with a previously well-functioning THR, one of whom was receiving steroids for systemic disease. No femoral component was revised for aseptic loosening.

Radiological outcome

Radiographs of all hips were available for analysis. The alignment of 83 femoral components was considered to be in a neutral position, but 21 had a deviation of > 3° from the neutral axis. Of these, 11 were in a varus and ten a valgus position. Most components had a stable radiological appearance during follow-up (Figure 1). Subsidence

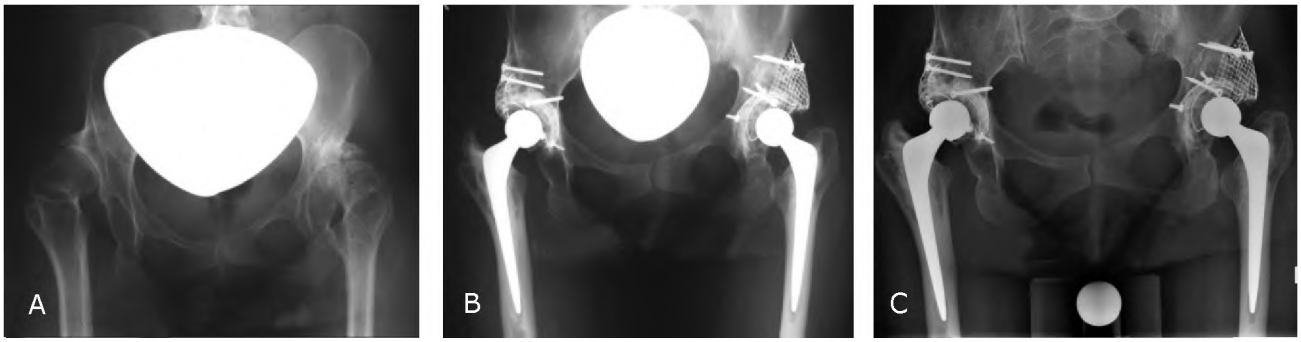


Figure 1A-C. Bilateral Exeter prosthesis in a 36-year-old woman with developmental dysplasia of the hip treated with extended acetabular reconstruction with wire meshes and bone impaction grafting (A) pre-operative anteroposterior pelvic radiograph, (B) immediate post-operative view, and (C) 11 years post-operatively with a stable view of the prostheses.

of more than 2 mm within the cement mantle occurred in three hips, none of which required revision. All three were asymptomatic. Migration of the femoral component with distal migration of the cement mantle was not seen. Femoral radiolucent lines were seen in six hips and involved a total of 16 zones. Four radiolucent lines were seen in zone 1, two in zones 7 and 8, and one in zones 2, 6 and 9 to 14. Two components had radiolucent lines in several zones. One of these has been revised for septic loosening. The other had progressive lines in zones 1, 2, and 6 to 8 for five years, but the patient reported only mild pain and no loss of function. One other hip had a progressive radiolucent line in zone 1.

Three components had showed one osteolytic zone in zones 1, 6 and 7, respectively. Rounding of the calcar was visible in 15 hips, but this did not produce any loss of calcar height in these hips. Hypertrophy and atrophy of the femoral cortex were present in one hip each. There were no fractures of the cement mantle or zones with sclerosis.

Other complications and re-operations not related to the femoral component

In three patients a deep wound infection was suspected post-operatively. Treatment consisted of immediate surgical debridement combined with local and intravenous antibiotics. All three patients recovered, and none developed septic loosening. A superficial wound infection was seen in three hips, and in five hips there was a postoperative haematoma. One patient had an extensive haematoma four months after THR, due to excessive thromboprophylaxis. A transient femoral and/or sciatic nerve palsy occurred in five patients; in four, there was isolated sensory disturbance, and in one a combined motor and sensory palsy. All five had developmental dysplasia with high dislocation of the hip joint. In each case conservative treatment led to complete recovery.

A total of 12 patients (12 hips, 11.5%) had a dislocation. Nine were treated conservatively and stabilised. Three patients underwent re-operation. Two had a femoral head exchange at five and 28 days post-operatively and the third had a revision of the acetabular component after 3.5 years. All patients became stable after surgery.

Table 1. Survival analysis for all Exeter femoral components.

Survival	Revision any reason (95%C.I.)	Revision any reason excl. infections (95%C.I.)	Revision aseptic (95%C.I.)	Radiographic loosening (95%C.I.)
Five-year survival	97.8 (91.6-99.5)	100 (100)	100 (100)	99.0 (93.2-99.9)
Seven-year survival	95.8 (86.6-98.7)	100 (100)	100 (100)	96.7 (86.1-99.3)

Heterotopic ossification was seen in 24 hips (23%); Brooker class 1 in eight; Brooker class II in ten and Brooker class III in six. The presence of the heterotopic ossification did not restrict movement in any patient. There were five acetabular revisions (4.8%), four for aseptic loosening and one for pain because of an unknown cause. During surgery in this patient the acetabular component was stable, however, the patient was relieved of pain following revision.

Survival analysis

Using Kaplan-Meier survival analysis with revision of the femoral component for any reason as the endpoint, the survival rate was 97.8% (95% CI 91.6 to 99.5) at five years and 95.8% (95% CI 86.6 to 98.7) at seven years. With aseptic loosening of the femoral component as the endpoint, the survival rate was 100% (95% CI 100) at five and seven years, and with radiological loosening of the component as the endpoint, the survival was 99% (95% CI 93.2 to 99.9) at five years and 96.7% (95% CI 86.1 to 99.3) at seven years (Table 1).

Discussion

Although the Exeter Universal femoral component is widely-used, we believe this to be the first report of the medium-term results of its use in patients under 40 years of age. In this group of patients, it has an acceptable survival rate at seven years post-operatively. None of the femoral components failed due to aseptic loosening, and the three that were revised were all infected. Despite a trend to use uncemented implants in young patients,[13-15] this study confirms that good results can be obtained with a cemented femoral component.

The wide range of available sizes and offsets (from 30.5 mm to 50 mm) meant that no custom-made components were needed. All patients were followed, and none were lost to follow-up, which is the ideal.[16]

One limitation of our study is the mean follow-up of 6.2 years, which means that the results are only medium-term. The number of hips with septic loosening was relatively high but this was associated with the surgery in only one patient, whereas the other two could be attributed to an acute haematogenous infection.

The dislocation rate of 11.5% was also relatively high. However, the reported incidence of dislocations in other series where a THR has been carried out in patients under 40 years varies between 0% and 18.2%.[17-27] We do not think the dislocation rate is related to the type of femoral component but it could be related to the previous operations which had been undertaken in seven of the 12 patients. Fortunately, nine of the 12 patients could be treated conservatively.

Reviewing the literature on patients under 40 years in general, femoral component survival is acceptable in all series, using both cemented and non-cemented components. A study on uncemented components of different designs by Duffy et al[18] had a slightly lower survival rate than reported survival rates of cemented components of 86% at ten years, using revision due to aseptic loosening as the endpoint. However, McAuley et al[28] had a survival rate of 98% of uncemented femoral components in their patient population under the age of 40 years at a mean follow-up of seven years. The most extensive data available relates to the Charnley femoral component. Joshi et al,[29] reported a survival rate of the original Charnley component of 99% at five years and 97% at ten years, with revision due to aseptic loosening as the endpoint. Chmell et al[17] described a survival rate of 95% at ten years with a variety of cemented femoral components in patients under the age of 30 years. The outcome of the Exeter femoral component at seven years in our series seems to be comparable to that of other cemented components in patients under the age of 40 years.

The best-reported long-term results of THR in patients under 40 years showed that the Charnley component had a survival rate of 75% after 20 years, with revision for any reason as the endpoint and a survival of 86% after 20 years with revision for aseptic loosening as the endpoint.[30]

There are several studies which report the survival of the Exeter femoral component in older patients.[1,2,31-36] These give a survival rate for patients with a mean age between 61 and 71 years ranging from 93% to 100% after ten years when femoral revision for aseptic loosening is taken as the endpoint. In our study group, the mean age was 31 years and we had a survival of 100% after seven years, with revision for aseptic femoral loosening taken as the endpoint.

The Exeter universal femoral component survives well in the medium term in young patients, despite the assumption that this group is more active, and will have a higher rate of wear.[37,38] Consequently, we will be keeping this cohort under review.

References

1. Williams HD, Browne G, Gie GA, et al. The Exeter universal cemented femoral component at 8 to 12 years: a study of the first 325 hips. *J Bone Joint Surg Br* 2002;84:324-34.
2. Hook S, Moulder E, Yates PJ, et al. The Exeter Universal Stem: a minimum ten year review from an independent centre. *J Bone Joint Surg Br* 2006;88:1584-90.
3. Schreurs BW, Bolder SB, Gardeniers JW, et al. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented cup: a 15- to 20-year follow-up. *J Bone Joint Surg Br* 2004;86:492-7.
4. Schreurs BW, van Tienen TG, Buma P, et al. Favourable results of acetabular reconstruction with impacted morsellised bone grafts in patients younger than 50 years: a 10- to 18-year follow-up of 34 cemented total hip arthroplasties. *Acta Orthop Scand* 2001;72:120-6.
5. Schreurs BW, Busch VJ, Welten ML, et al. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86:2385-92.
6. Sugioka Y. Transtrochanteric anterior rotational osteotomy of the femoral head in the treatment of osteonecrosis affecting the hip: a new osteotomy operation. *Clin Orthop Relat Res* 1978;130:191-201.
7. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty: an end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 1969;51:737-55.
8. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br* 1996;78:185-90.
9. Gruen TA, McNiece GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;141:17-27.
10. Harris WH, McCarthy JC, O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg Am* 1982;64:1063-7.
11. Loudon JR, Older MW. Subsidence of the femoral component related to long-term outcome of hip replacement. *J Bone Joint Surg Br* 1989;71:624-8.
12. Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr. Ectopic ossification following total hip replacement. *J Bone Joint Surg Am* 1973;55:1629-32.
13. No authors listed. Norwegian Arthroplasty Register. Annual report 2007. http:// www.haukeland.no/nrl/Report2007.pdf (date last accessed 23 September 2008)
14. No authors listed. Norwegian Arthroplasty Register. Annual report 2006. http:// www.jru.orthop.gu.se/ (date last accessed 23 September 2008).
15. No authors listed. Australian Orthopaedic Association. National Joint Replacement Registry; annual report 2007. http://www.aoa.org.au/docs/njarep07.pdf (date last accessed 23 September 2008).
16. Murray DW, Britton AR, Bulstrode CJ. Loss to follow-up matters. *J Bone Joint Surg Br* 1997;79:254-7.
17. Chmell MJ, Scott RD, Thomas WH, Sledge CB. Total hip arthroplasty with cement for juvenile rheumatoid arthritis: results at a minimum of ten years in patients less than thirty years old. *J Bone Joint Surg Am* 1997;79:44-52.
18. Duffy GP, Berry DJ, Rowland C, Cabanela ME. Primary uncemented total hip arthroplasty in patients < 40 years old: 10- to 14-year results using first-generation proximally porous-coated implants. *J Arthroplasty* 2001;16:140-4.
19. Bessette BJ, Fassier F, Tanzer M, Brooks CE. Total hip arthroplasty in patients younger than 21 years: a minimum, 10-year follow-up. *Can J Surg* 2003;46:257-62.
20. Cage DJ, Granberry WM, Tullos HS. Long-term results of total arthroplasty in adolescents with debilitating polyarthropathy. *Clin Orthop Relat Res* 1992;283:156-62.
21. Dudkiewicz I, Salai M, Ganel A, Blankstein A, Chechik A. Total hip arthroplasty in patients younger than 30 years of age following developmental dysplasia of hip (DDH) in infancy. *Arch Orthop Trauma Surg* 2002;122:139-42.
22. Dudkiewicz I, Salai M, Israeli A, Amit Y, Chechick A. Total hip arthroplasty in patients younger than 30 years of age. *Isr Med Assoc J* 2003;10:709-12.
23. Kitsoulis PB, Stafilas KS, Siamopoulou A, Soucacos PN, Xenakis TA. Total hip arthroplasty in children with juvenile chronic arthritis: long-term results. *J Pediatr Orthop* 2006;26:8-12.
24. Ruddlesdin C, Ansell BM, Arden GP, Swann M. Total hip replacement in children with juvenile chronic arthritis. *J Bone Joint Surg Br* 1986;68:218-22.
25. Torchia ME, Klassen RA, Bianco AJ. Total hip arthroplasty with cement in patients less than twenty years old: long-term results. *J Bone Joint Surg Am* 1996;78:995-1003.
26. Piston RW, Engh CA, de Carvalho PI, Suthers K. Osteonecrosis of the femoral head treated with total hip arthroplasty without cement. *J Bone Joint Surg Am* 1994;76:202-14.
27. Yoo JJ, Kim YM, Yoon KS, et al. Contemporary alumina-on-alumina total hip arthroplasty performed in patients younger than forty years: a 5-year minimum follow- up study. *J Biomed Mater Res B Appl Biomater* 2006;78:70-5.
28. McAuley JP, Szuszczewicz ES, Young A, Engh CA Sr. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-25.
29. Joshi AB, Porter ML, Trail IA, et al. Long-term results of Charnley low-friction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75:616-23.
30. Sochart DH, Porter ML. Long-term results of Charnley low-friction arthroplasty in young patients who have congenital dislocation, degenerative osteoarthritis, or rheumatoid arthritis. *J Bone Joint Surg Am* 1997;79:1599-617.
31. Franklin J, Robertsson O, Gestsson J, Lohmander LS, Ingvarsson T. Revision and complication rates in 654 Exeter total hip replacements with a maximum followup of 20 years. *BMC Musculoskeletal Disord* 2003;4:6.

32. Arthursson AJ, Furnes O, Espehaug B, Havelin LI, Söreide JA. Prosthesis survival after total hip arthroplasty: does surgical approach matter? Analysis of 19,304 Charnley and 6,002 Exeter primary total hip arthroplasties reported to the Norwegian Arthroplasty Register. *Acta Orthop* 2007;78:719-29.
33. Chiu KH, Shen WY, Cheung KW, Tsui HF. Primary Exeter total hip arthroplasty in patients with small femurs: a minimal of 10 years follow-up. *J Arthroplasty* 2005;20:275-81.
34. Rockborn P, Olsson SS. Loosening and bone resorption in Exeter hip arthroplasties: review at a minimum of five years. *J Bone Joint Surg Br* 1993;75:865-8.
35. Sherfey JJ, McCalden RW. Mid-term results of Exeter vs. Endurance cemented stems. *J Arthroplasty* 2006;21:1118-23.
36. Fowler JL, Gie GA, Lee AJ, Ling RS. Experience with the Exeter total hip replacement since 1970. *Orthop Clin North Am* 1988;19:477-89.
37. Kobayashi S, Eftekhar NS, Terayama K, Joshi RP. Comparative study of total hip arthroplasty between younger and older patients. *Clin Orthop Relat Res* 1997;339:140-51.
38. Schmalzried TP, Huk OL. Patient factors and wear in total hip arthroplasty. *Clin Orthop Relat Res* 2004;418:94-7.

Chapter 4

Cemented polyethylene cups in patients younger than 40 years

D.C.J. de Kam
J.W.M. Gardeniers
J.C.M. Hendriks
R.P.H. Veth
B.W. Schreurs

Clinical Orthopaedics and Related Research 2009;467:1753-64.

Abstract

Although uncemented cup implants frequently are used in young patients, we believe long-term survival rates of cups in these patients are somewhat disappointing, and therefore we have continued to use cemented cups in primary THA, even in young patients. However, in cases of acetabular bone stock defects, we also use bone impaction grafting.

We prospectively followed 130 patients with 175 cemented cups; no patients were lost to followup. The mean age of the patients at surgery was 31 years (range, 16–39 years). An acetabular reconstruction with bone impaction grafting was performed in 84 hips (48%). The minimum followup was 2 years (average, 8.1 years; range, 2.0–18.5 years).

Twenty-one of the 175 cups (12%) were revised at an average of 8.1 years (range, 2.0–18.5 years). Reasons for revision were infection (one early, seven late), recurrent dislocations (two), traumatic loosening (one), and aseptic loosening (10). The 10-year survival rate of all cemented cups with end point of revision for any cause was 85%. Survival with end point of aseptic loosening of all cups was 92%. Survival with end point of revision for aseptic loosening was 90% for the cups without impaction grafting and 95% for the cups with impaction grafting.

We believe cemented acetabular cups in young patients have acceptable midterm survival; however, in the case of acetabular bone defects, we recommend reconstruction with impaction grafting.

Introduction

Obtaining a satisfying long-term survival of THAs in patients younger than 40 years remains a challenge. Young patients must function longer with their THA than the typical patient who has a THA, and they also engage in a higher level of activity, which is associated with higher revision rates.[19,27] Therefore, this population is more dependent on durable implants with excellent long-term survival. Although stem survival is acceptable in most studies, in general, cup survival is the weakest link in patients younger than 40 years.[5,8,9,15,18,20,25] The difference in reported survival rates between the cup and stem varies from 1% (97% [stem] versus 96% [cup][18]) to 11% (98.3% [stem] versus 87.6% [cup][20]). Despite attempts to improve cup designs and using new materials in THA, the acetabular component still shows lower survival rates than femoral implants.

One popular option is to implant uncemented acetabular cups in young patients as part of a total uncemented THA or hybrid THA (uncemented cup, cemented stem). Although cement in young patients commonly is not used,[1,24,35] we always have implanted cemented cups in patients of all ages, but with one substantial modification: in all patients with substantial acetabular bone stock deficiencies, we have reconstructed this bone stock loss using impaction bone grafting with a cemented cup. Secondary osteoarthritis resulting from underlying diseases in these young patients often is seen with associated loss of acetabular bone stock (for example, in developmental dysplasia of the hips and juvenile rheumatoid arthritis). With this approach using cemented cups in young patients for many years, we asked whether there were any differences between cemented cups in young patients (younger than 40 years) with and without reconstruction with impaction grafting concerning (1) clinical scores, (2) revisions, (3) complications, (4) radiographic appearances, (5) polyethylene wear, and (6) survival.

Materials and Methods

We retrospectively reviewed prospectively collected data of all 130 patients (175 hips) who had a primary THA in our department between January 1988 and July 2004 and who were younger than 40 years at the time of index surgery. We used a cemented femoral stem and cemented acetabular polyethylene cup in all patients. In patients with acetabular bone deficiencies, these deficiencies were reconstructed with the impaction grafting technique. The decision to use bone impaction grafting was made based on the preoperative radiographs in combination with intraoperative findings. A trial cup was placed on the transverse ligament; in the case of a protrusion hip or a superolateral rim defect, a reconstruction was performed. Eighty-four hips (48%) had impaction grafting whereas 91 (52%) did not have impaction grafting. Because a cemented THA was our only treatment technique, patients with all diagnoses were included (Table 1). The majority (62%) of the patients had developmental dysplasia of the hips, rheumatoid arthritis, or corticosteroid-induced avascular necrosis.

Fifty-five (42%) patients were males and 75 (58%) were females. Eighty-nine (51%) THAs were on the left side and 86 (49%) were on the right. Forty-five (35%) patients had bilateral THAs. The average age of the patients at index surgery was 31.3 years (range, 16–39 years). The mean body mass index was 25.5 (range, 17.9–36.3). According to the classification of Charnley,[7] 46 hips were in Category A, 71 in B, and 58 in C. We followed all patients in this prospective cohort on a regular basis and the minimum followup was 2 years (average, 8.1 years; range, 2.0–18.5 years) after surgery. During followup, six patients (eight hips) died of causes not related to the hip or hip surgery. All patients who died were followed on a regular basis and their data included; none had revision surgery. Of the original group of 175 cups, the data of only one patient were incomplete. Based on a telephone interview, the prosthesis of this patient functioned well; however, a recent radiograph was missing.

We categorized acetabular defects in accordance with the classification system of the American Academy of Orthopaedic Surgeons.[10] Eighty-six hips (49%) had an acetabular deficiency. Type I segmental deficiencies occurred in 16 hips, Type II cavitary defects in

Table 1. Indications for primary THA with and without reconstruction with bone impacting grafting.

Indication	Number of hips		
	Without bone impaction grafting	With bone impaction grafting	Total
Developmental dysplasia of the hip	10	32	42
Rheumatoid arthritis	17	10	27
Perthes' disease	4	4	8
Avascular necrosis of unknown cause	6	2	8
Epiphyseal dysplasia	5	2	7
Posttraumatic osteoarthritis	2	4	6
Bechterew's disease	3	2	5
Posttraumatic avascular necrosis	4	1	5
Morquio's disease	1	3	4
Epiphysiolysis	1	3	4
Septic coxitis	2	1	3
Protrusio acetabuli	0	3	3
Osteomyelitis	0	3	3
Spontaneous fusion hip of unknown cause	1	1	2
Osteogenesis imperfecta	0	2	2
Polycystic disease of unknown cause	2	0	2
Arthritis Psoriatic arthritis	0	1	1
Gigantism of unknown cause	0	1	1
Pseudohypoparathyroidism	1	0	1
Monoarthritis of unknown cause	0	1	1
Alcohol-induced avascular necrosis	1	0	1
Corticosteroid-induced avascular necrosis	31	8	39
Systemic lupus erythematosus			9
Kidney transplantation/nephropathy			7
Subarachnoid hemorrhage			4
Non-Hodgkin's lymphoma			3
Crohn's disease			3
Cerebral aneurysm			2
Head trauma			2
Thrombocytopenia			2
Hypothalamus hormone substitution			1
Germ cell tumor			1
Aplastic anemia			1
Pituitary adenoma			1
Wegener's disease			1
Acute lymphatic leukemia			1
Meduloblastoma			1
Total	91	84	175

39 hips, and Type III combined deficiencies in 29 hips. One patient (two hips) had ankylosis of the hips, a Type V deficiency. Using impaction grafting, we reconstructed all deficiencies, including mild cavitary defects; however most were larger defects.

Differences between the two groups (with and without impaction grafting) were analyzed regarding diagnosis and gender (chi square test, both $p = 0.001$). In the group with an acetabular reconstruction, a larger proportion was female and was diagnosed with developmental dysplasia of the hips compared with the Group without reconstruction. There were no differences regarding age at surgery, side, bilateral THAs, followup, type of cup used, cup inner diameter, and body mass index between the two groups.

Two-thirds of the operations (67%) were performed by or under the supervision of two senior faculty orthopaedic surgeons (BWS, JWMG). A posterolateral approach without trochanteric osteotomy was used in all hips, with the exception of two. Intraoperatively, in one patient, a preplanned Sugioka procedure was converted to a THA; however, a trochanteric osteotomy already had been performed. In the other patient, a trochanteric osteotomy was performed in a technically demanding hip with a short femoral neck. In one patient, an additional anterior approach was needed because of ankylosis of the hip. All acetabular deficiencies were reconstructed (with the exception of one case) with impaction grafting using autografts and/or allografts in 84 hips (48%); this technique has

been described in detail.[28-30] Segmental bone defects first were reconstructed with wire meshes before the morselized bone graft was impacted and a conventional full polyethylene cup was cemented. In one patient, we reconstructed a lateral rim deficiency without impaction grafting using a solid autograft fixed with two screws. In one of the ankylosed hips (Type V deficiency), we did not use impaction grafting. We used allografts only with impaction grafting in four hips (4.8%), autografts only in 72 hips (85.7%), and combined allografts and autografts in eight hips (9.5%). Allografts were used when the original femoral head was not large enough to reconstruct the defect or in cases with pathologic femoral heads (for example, avascular necrosis of the femoral head). In three cases, instead of a solitary metal mesh, a solid fragment was used in combination with impaction grafting. In two of these cases, a minor segmental defect in the medial wall was closed using a cortical-trabecular fragment of a femoral head. A wire mesh was placed medial on top of the fragment and the acetabulum was reconstructed with impaction grafting. In the third case, a cortical head fragment was used to support the anterior rim together with a rim mesh in a reconstruction. The number of femoral heads used as grafts varied from one to four. In 40 hips (48%), metal wire mesh was used for acetabular reconstruction with impaction grafting (10 medial wall meshes, 39 rim meshes). In nine early cases, we placed a mesh on top of the bone graft just before cementation, but this mesh was not part of a segmental defect reconstruction. However, after we realized this mesh did not add any stability to the reconstruction and there were no signs of damaging of the graft or graft healing by direct contact with cement, we abandoned the use of a mesh for this purpose.

We used 79 (45%) Exeter™ Contemporary™ cups with an inner diameter of 28 mm (n = 75) and 22.225 mm (n = 5) (Stryker Howmedica, Newbury, UK), 71 (41%) Charnley® Elite™ cups with an inner diameter of 22.225 mm (n = 6) or 28 mm (n = 65) (DePuy, Leeds, UK), and 25 (14%) Müller/AlloPro cups with an inner diameter of 32 mm (n = 19), 28 mm (n = 2), or 22.225 mm (n = 4) (Sulzer, Winterthur, Switzerland). For the femoral component, we used an Exeter™ stem in 111 cases, a Charnley® Elite™ stem in 48 cases, and a Müller stem in 16 cases. All femoral heads used were made of a cobalt-chrome alloy; no ceramic implants were used.

We cemented acetabular components with a third-generation cementing technique. In the directly cemented cups, after reaming, multiple small drill holes were made with a 2.6-mm drill. After using pulse lavage, vacuum-mixed cement was injected directly from the cement gun and the cement was pressurized by a seal. In cases of reconstruction with bone grafts, we reamed the acetabulum, made multiple drill holes in sclerotic areas, and irrigated the acetabulum. Next the bone graft was impacted. Again, vacuum-mixed cement was injected and pressurized and the cup was inserted. Before 1989, we used Palacos® bone cement (Merck, Darmstadt, Germany); however, since 1989, we have used Surgical Simplex® (Stryker Howmedica). In 165 cases (94%), cement loaded with antibiotics was used. All patients received antibiotic prophylaxis consisting of 2 g cefazolin intravenously just before surgery. Other precautionary measures to prevent infections were use of an operating theater with laminar airflow and use of two pairs of sterile gloves.

Postoperatively, all patients received thrombosis prophylaxis with low-molecular-weight heparin for 6 weeks, or before 1999, with acenocoumarol (the individual dosage regimens regulated with regular coagulation tests) for 3 months. To prevent heterotopic ossification, we used nonsteroidal antiinflammatory drugs (NSAIDs) for 7 days. In six patients in whom NSAIDs were contraindicated, we administered one dose (7 Gy) of radiotherapy 1 day postoperatively.

Patients without acetabular reconstruction were mobilized under supervision of a physiotherapist after 1 or 2 days. Full weightbearing was increased in 2 to 6 weeks with the aid of one or two crutches. The patients who underwent impaction grafting were mobilized according to a modified protocol; in the first 6 weeks, only 10% weightbearing was allowed and then 6 to 12 weeks of 50% weightbearing using two crutches was allowed. After 12 weeks, full weightbearing mobilization was allowed. Thirty-one hips had

such an extensive reconstruction of major defects that several weeks of bed rest were maintained ranging from 1 to 6 weeks. We used this modified mobilization protocol to ensure graft incorporation before full weightbearing.

Routine follow-ups were scheduled at 6 weeks; 3, 6, and 12 months; and yearly or biannually thereafter. At our outpatient clinic, student researchers not participating in the treatment performed clinical analysis using the Harris hip score,[17] the Oxford Hip Questionnaire Score (since 1998),[11] and visual analog scales for pain during rest and physical activity on a scale from 0 (no pain) to 100 (unbearable pain). We report the clinical scores of all patients excluding the 21 patients whose hips were revised during followup.

All anteroposterior pelvis and lateral radiographs of all hips were analyzed on a consensus basis by two of the authors (DCJDK, BWS). Radiographic evaluation included assessment of cup position, loosening of the acetabular component, polyethylene wear, presence of osteolysis, structural quality of the bone graft, application and position of the meshes, migration, heterotopic ossification, and fracture of the cement, mesh, or prosthesis. Radiolucent lines and osteolysis were recorded according to the three acetabular zones as described by DeLee and Charnley.[12] Radiographic loosening was defined as 2 mm or greater demarcation in two or three zones around the acetabular component, progressive demarcation, 3 mm or greater component migration, 5° or greater component tilting, and/or cement or prosthesis fracture. We determined cup migration (> 3-mm shift in any direction or > 5° tilting) in relation to the interteardrop line instead of the Kohler line.[16] Position of the cup of 45° ± 10° was considered normal.[26] We calculated polyethylene wear using the method of Dorr and Wan.[13] All measurements were corrected for magnification. Heterotopic ossification was classified according to the system of Brooker et al..[6] Graft incorporation was defined as the presence of the crossing of trabecular bone on the bone-graft interface on the radiographs. Clinical failure was defined as the need for revision of the acetabular component for any reason.

We calculated Kaplan-Meier curves to study the survival (time to revision). The end points were (1) cup revision for any reason, (2) cup revision for any reason excluding infections, (3) cup revision for aseptic loosening, and (4) radiographic signs of cup loosening. With an average followup of 8.1 years, 30% of all patients had a followup longer than 10 years. The log-rank test was used to test the differences in survival between cups with and without impaction grafting. Differences in outcomes between the groups were determined with the Student's t-test (continuous variables after checking for normal distribution) or chi square test (nominal variables).

Results

Clinical outcome

The outcome of the Harris hip score and the Oxford Hip Questionnaire Score improved ($p < 0.0001$) after surgery for both groups; there were no differences in preoperative and postoperative clinical outcomes between the cups with and without acetabular reconstruction (Table 2). The postoperative experienced pain score was low.

Revisions

The number of revisions in the groups with and without bone grafts was not different ($p = 0.152$). At last followup, 21 of the 175 cups (12%) had been revised, seven of which had reconstruction with impaction grafting (Table 3). Reasons for revision were infection (eight), recurrent dislocations (two), traumatic loosening (one), and aseptic loosening (10). Revision for aseptic loosening was performed in 10 acetabular implants (5.7%). The cup only was revised in eight cases and the cup and stem were revised in two cases. Four of the 10 revised cups had reconstruction with impaction grafting and six cups were implanted with standard techniques without any graft. The failed cups reconstructed with impaction grafting were revised after 4.1, 9.8, 16.2, and 16.8 years (average, 11.7 years). The six directly cemented cups were revised after an average of 4.0 years

(range, 1.1–10.0 years). The time to revision for aseptic loosening was longer (p = 0.032) for the reconstructed cups with impaction grafting than for the cups implanted with standard techniques. The eight infected hips (4.6%) all had revision because of culture-proven infection of the implant. The average time to revision for septic loosening was 5.3 years (range, 2.2–8.1 years). Staphylococcus epidermidis was isolated in three, Staphylococcus aureus in two, Proprioni in two, Pseudomonas aeruginosa in one, and Streptococcus oralis in one. As a result of recurrent dislocations, two cups (1.1%) were revised at 3.5 and 8.6 years after the index operation. One implant (0.6%) was radiographically and clinically loose after trauma and needed revision of both components.

Complications

We observed similar (p = 0.959) numbers of overall complications in the groups with and without bone grafts. However, dislocations were more common (p = 0.045) in the Group without bone grafts than in the group with bone grafts (15 versus 5, respectively). Patients without reconstruction with impaction grafting had an increased dislocation chance of 1:2.9. During followup, there were nine intraoperative complications and 30 postoperative complications (Table 4). One additional stem was revised because of aseptic loosening and two femoral heads were exchanged because of recurrent dislocations. Seven hips underwent additional surgery because of postoperative complications (Table 4).

Radiographical evaluation

There were no differences between the cups with and without acetabular reconstruction concerning the occurrence of cup migration, radiographic loosening, or the presence of osteolysis, cysts, and abnormal cup position (Table 5). Cups with impaction grafting had fewer radiolucent lines (p = 0.02) and fewer lines in Zone I (p = 0.001) (Table 5). All lines, except two, were on the bone-cement interface. In 28 (48%) of the 58 cups with radiolucent lines, the lines were progressive. Of the 175 hips, 160 were radiographically stable (Figure 1). Fifteen cups were difficult to evaluate because of overlap of the metal mesh (11 Zone I; four Zones I + II). We observed graft osteolysis in only one patient with impaction grafting; all other grafts were fully incorporated. The hip revised because of traumatic loosening had a fracture in Zone II of the acetabulum; no other fractures were seen. Fifteen (8.6%) cups were radiographically loose, three had cup migration (after 1.8, 9.8, and 11.2 years postoperatively), and 12 had evident radiolucent lines in all zones and/or severe osteolysis; 12 of these cups were revised (Table 3).

Table 2. Outcome of clinical questionnaires.

Questionnaire	Preoperative score			Postoperative score		
	With bone impaction grafting	Without bone impaction grafting	P-value	With bone impaction grafting	Without bone impaction grafting	P-value
Harris hip score	48 (15–81) (n = 46)	50 (28–82) (n = 50)	0.672	92 (35–100) (n = 72)	96 (12–100) (n = 73)	0.546
Oxford Hip Questionnaire Score	39 (30–52) (n =9)	38 (12–52) (n = 15)	0.100	17 (12–45) (n = 70)	15 (12-41) (n = 72)	0.151
VAS pain at rest	NA	NA		0 (0–75) (n = 70)	0 (0–70) (n = 71)	0.260
VAS pain during physical activity	NA	NA		10 (0–90) (n = 70)	0 (0–100) (n = 71)	0.267

Values are expressed as median, with range in parentheses; VAS = visual analog scale; NA = not available.

Table 3. Overview of the revised cups (n = 21).

Case	Follow-up	Cause	Part revised	Bone impaction grafting	Indication	Years to radiographic loosening	Previous operations
5	7.3	Infection	THA	No	Corticosteroids (systemic lupus erythematosus)		No
20	6.1	Infection	THA	Yes	Avascular necrosis of unknown cause		Yes
50	5.7	Infection	THA	No	Corticosteroids (Crohn's Disease)	2.6	Yes
68	8.1	Infection	THA	No	Rheumatoid arthritis		No
87	5.3	Infection	THA	No	Developmental dysplasia of the hip	5.2	Yes
104	4	Infection	THA	No	Corticosteroids (subarachnoid bleeding)		No
113	3.4	Infection	THA	Yes	Corticosteroids (pituitary adenoma)		Yes
123	2.2	Infection	THA	No	Medial column fracture	0.5	Yes
111	8.6	Recurrent dislocations	Cup	No	Posttraumatic coxarthrosis		No
160	3.5	Recurrent dislocations	Cup	Yes	Corticosteroids (cerebral aneurysm)		Yes
84	10.3	Traumatic loosening	THA	No	Corticosteroids (head trauma)	9.9	No
29	4.1	Aseptic loosening	Cup	Yes	Rheumatoid arthritis	4	No
41	2.3	Aseptic loosening	Cup	No	Corticosteroids (systemic lupus erythematosus)	2.2	Yes
45	3.1	Aseptic loosening	Cup	No	Spontaneous fusion of unknown cause	0.3	No
49	1.1	Aseptic loosening	Cup	No	Corticosteroids (kidney transplantation)	4.2	No
77	16.8	Aseptic loosening	Cup	Yes	Posttraumatic coxarthrosis	16.6	Yes
78	9.8	Aseptic loosening	Cup	Yes	Coxarthritis	9.8	Yes
79	16.2	Aseptic loosening	THA	Yes	Developmental dysplasia of the hip	16.2	No
82	10	Aseptic loosening	Cup	No	Developmental dysplasia of the hip	5.2	No
90	6.4	Aseptic loosening	THA	No	Developmental dysplasia of the hip		No
153	1.1	Aseptic loosening	Cup	No	Epiphysiolysis		Yes

Polyethylene wear

There was no difference in polyethylene wear rates between the cups with and without impaction grafting ($p = 0.539$ in 154 unrevised cups and $p = 0.525$ in the 21 revised cups) (Table 5). When looking at all cups (with and without acetabular reconstruction), the revised and radiographically loose cups had more wear compared with the cups that were not revised (both $p < 0.0001$). Patients with an abnormal position of the cup had similar ($p = 0.196$) polyethylene wear rates to those who had a normal position. Analysis of polyethylene wear rates of cups with different inner diameters showed no differences (independent t test, 22 versus 28 mm: $p = 0.135$, 22 versus 32 mm: $p = 0.484$, 28 versus 32 mm: $p = 0.620$).

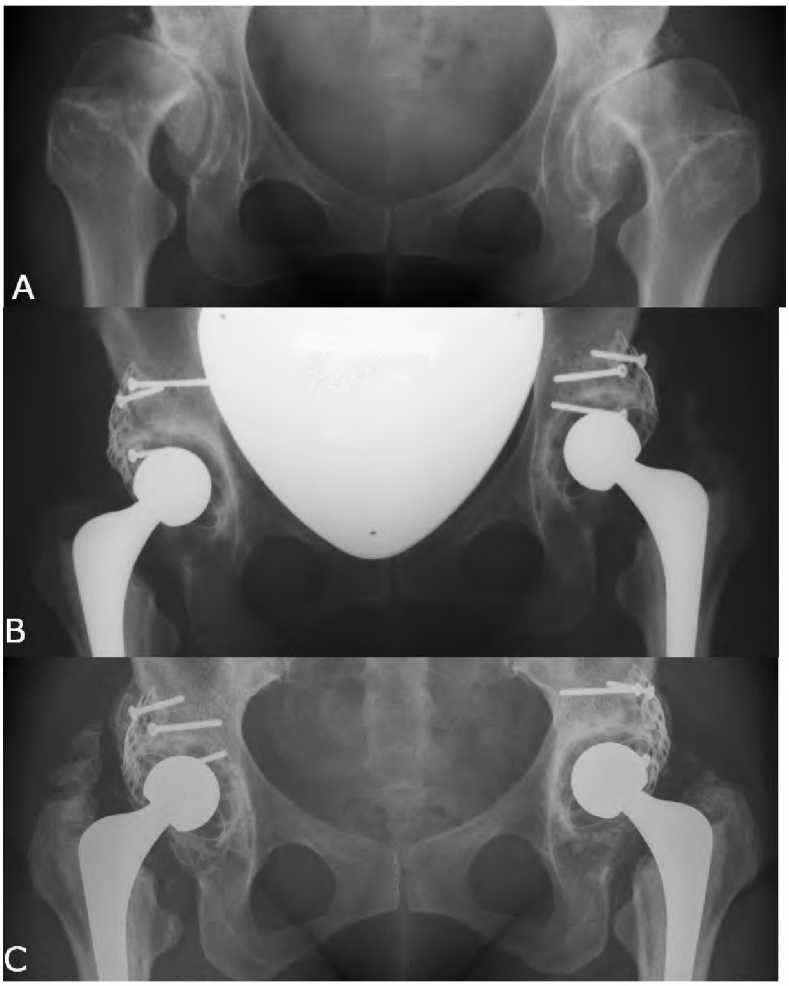


Figure 1A-C. The radiographs illustrate reconstruction of the acetabuli in a 34-year-old woman with bilateral DDH (Crowe Grade 3). (A) A preoperative anteroposterior radiograph shows the acetabuli. (B) An anteroposterior radiograph taken immediately postoperatively shows the THAs with the acetabuli reconstructed with impaction grafting. (C) An anteroposterior radiograph taken 12 years postoperatively shows the THAs remain radiographically stable, but Brooker Classes III (left) and I (right) heterotopic ossifications are visible.

Survival analysis

There were no differences in survival after 10 years between the groups with and without bone impaction grafting (Table 6). The midterm survival rates of all cemented polyethylene cups varied from 85% to 92% at 10 years with four end points (Table 6; Figures 2 and 3). Cup survival with an end point of radiographic loosening was 89% (95% confidence interval, 83%–95%).

Discussion

The use of cemented THA in young patients is not very popular and most surgeons will use uncemented or resurfacing hips in these patients. However, we have continued to use only cemented implants in THA even in young patients. In our view, the real challenge in THA in these young patients is to manage the commonly seen acetabular deficiencies. In cases of acetabular defects, we reconstruct these deficiencies with impaction bone grafting. We questioned whether there was a difference in clinical outcome, revisions, complications, radiographic appearances, polyethylene wear, and survival between the cups implanted with an acetabular reconstruction with impaction grafting and those implanted with standard cementing techniques.

Table 4. Overview of complications.

Type of complication	Number
Intraoperative complications (n = 9)	
Entrapment of sciatic nerve during reposition, permanent damage	1
False route femur	1
Incomplete femoral fracture	2
Malposition cup	1
Malposition stem	1
Instrument failure	1
Suspicion of breakthrough of sterility	2
Postoperative complications (n = 30)	
Superficial wound infection	3
Single dislocation	9
Recurrent dislocations	6
Sensory nerve palsy	4
Sensory and motor nerve palsy	1
Hematoma	6
Bleeding after 4 months	1
Heterotopic ossifications (n = 44)	
Brooker Class I	15
Brooker Class II	19
Brooker Class III	10
Postoperative complications leading to revision (no cup revision) (n = 3)	
Stem revision for aseptic loosening	1
Head exchange because of recurrent dislocations	2
Postoperative complications requiring surgical intervention (no revision) (n = 7)	
Deep wound infection	4
Heterotopic ossifications	1
Traumatic dislocation	1
Persistent motor and sensory nerve palsy	1

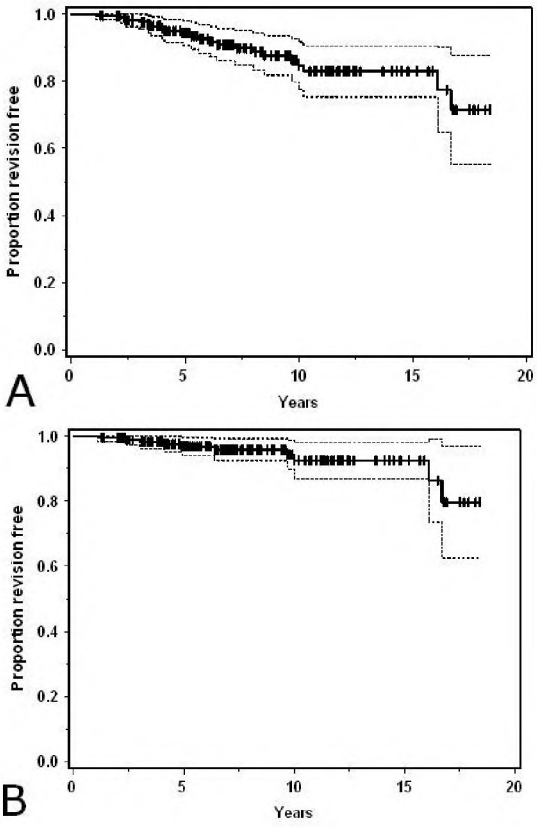


Figure 2A-B. Kaplan-Meier survival curves with 95% confidence intervals (broken lines) of all cups with end points of (A) revision for any reason and (B) revision for aseptic loosening are shown. The vertical bars indicate the censored data points.

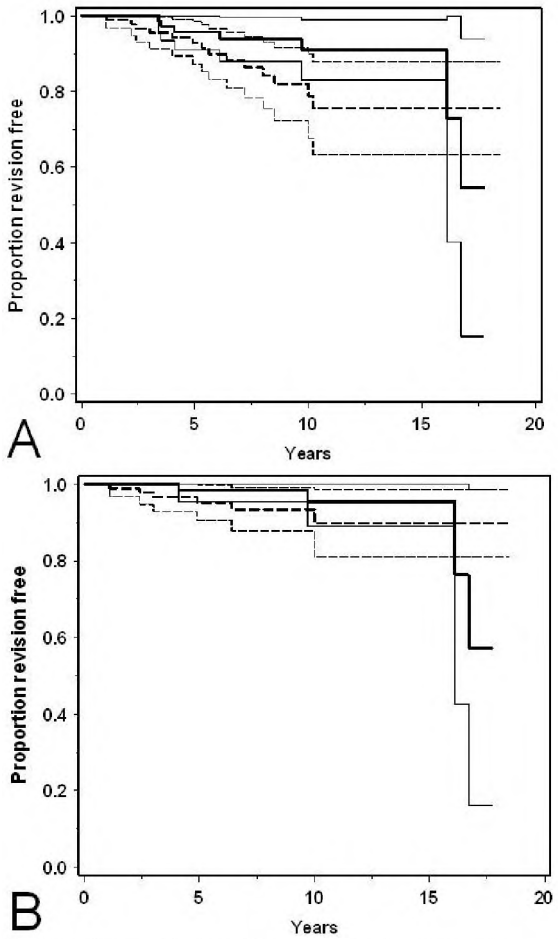


Figure 3A-B. Kaplan-Meier survival curves of cups without impaction grafting (thick broken line, 95% confidence intervals in thin broken lines) and cups with impaction grafting (thick solid line, 95% confidence intervals in thin solid lines) with end points of (A) revision for any reason and (B) revision for aseptic loosening are shown.

Our study has several limitations: short followup, lack of assessment of activity levels, clinical interobserver variability, heterogeneous group, no comparison with other reconstruction techniques, and different types of implants used. With no patients lost to followup, our followup is representative and reliable for the midterm results,[22] and longterm followup (> 15 years) was not available at the time of this review. Our results can be biased by an important factor we did not evaluate: the level of activity.

Theoretically, with restoration of the affected hip(s) into well-functioning artificial joints, most patients will increase their level of activity. However, young patients undergoing THA with acetabular deficiencies and therefore more complex reconstructions could still have a lower level of activity after surgery relative to primary cemented cups.

However, the average wear of the cups with impaction grafting was the same as the cups without impaction grafting (both 0.08 mm/year). Provided that activity is a major cause of polyethylene wear, this might imply the level of activity is similar in these two groups. Several studies suggest the revision and polyethylene wear rates are correlated to level of activity.[2,19,27,31,38] Additional research on level of activity and impaction grafting in young patients is necessary to confirm this hypothesis. The clinical questionnaires were obtained by student researchers who did not participate in the treatment. Multiple researchers were involved in the data collection and interobserver variability has not been tested; however, all researchers were trained and supervised to obtain these questionnaires correctly.

Table 5. Radiographic findings of all cups (n = 175) and cups with (n = 84) or without (n = 91) reconstruction with bone impaction grafting.

Radiographic finding	All	With bone impaction grafting	Without bone impaction grafting	p value (where appropriate)
Radiographical loosening	15	5	10	0.608
Cup migration	3	1	2	0.234
Radiolucent lines	58	18	40	0.02
Zone I	18	3	15	0.001
Zone II	2	0	2	
Zone III	17	9	8	
Zone I + II	4	2	2	
Zone II + III	5	2	3	
Zone I + III	5	1	4	
Zone I + II + III	7	1	6	
Osteolysis	11	5	6	0.861
Zone I	7	2	5	
Zone II	1	1	0	
Zone III	3	2	0	
Cysts	1	0	0	0.033
Zone I	1	0	0	
Zone II	0	0	0	
Zone III	0	0	0	
Cup position				
Neutral position (35°–55°)	160	77	83	
Abnormal position	15	7	8	0.914
Vertical (> 55°)	12	6	6	
Horizontal (< 35°)	3	1	2	
Polyethylene wear				
Mean nonrevised cups (mm/year)	0.080	0.076	0.084	0.539
Mean revised cups (mm/year)	0.214	0.182	0.230	0.525

Table 6. The 10-year survival rates of all cups and cups with and without reconstruction with bone impaction grafting using Kaplan-Meier estimates.*

End point	All cups	Without bone impaction grafting	With bone impaction grafting	Log-rank p value
Revision for any reason	85% (78%–92%)	79% (68%–90%)	91% (82%–99%)	0.21
Revision for any reason excluding infections	91% (85%–97%)	87% (78%–99%)	94% (87%–100%)	0.56
Revision for aseptic loosening	92% (87%–98%)	90% (81%–99%)	95% (89%–100%)	0.73

*95% confidence interval in parentheses.

The clinical scores were comparable between the two groups and comparable to published scores (Table 7). Although the cups reconstructed with bone impaction grafting were the more demanding procedures, no clinical differences were seen.

Although revision rates in both groups were comparable, the time to revision was longer in the cups reconstructed with bone impaction grafting. We have no clear explanation for this observation; possibly the cement-bone interface was better in cups with bone impaction grafting with better interdigitation of the cement into the bone.[36] This also may explain the lower incidence of radiolucent lines in the cups reconstructed with bone impaction grafting. The number of revisions for septic loosening was relatively high during this midterm followup study (4.6%). Only one septic loosening likely was related to the surgery; we considered all other infections acute hematogenous infections of previously well-functioning prostheses. The use of corticosteroids and newer rheumatic disease-modifying drugs, which were used in most of the infection cases, can explain this higher risk of infection.[3,4] Sochart and Porter[33] had only two infections in their study, but

Table 7. Reported outcomes of the Harris hip score in young patients <40 years for primary THA.

Study	Questionnaire	Preoperative score	Postoperative score	Paired t-test p value
Chiu et al.[8]	Harris hip score	44 (26-74)	88 (74-99)	<0.001
Duffy et al.[15]	Harris hip score	51	92	<0.001
Current study				
With bone impaction grafting	Harris hip score	48 (15–81)	92 (35–100)	<0.001
Without bone impaction grafting	Harris hip score	50 (28–82)	96 (12–100)	<0.001

Values are expressed as median (current study) or means (other studies), with range in parentheses.

both were in patients with rheumatoid arthritis. Still, our revision rate for septic loosening of 4.6% is relatively high in contrast to other studies, such as that of Joshi et al.,[18] with an infection rate of 1.3%. Remarkably, many septic loosenings occurred late (> 2 years postoperatively).

The cups reconstructed with impaction grafting showed fewer complications by having fewer dislocations than the cups implanted by standard techniques. This might be attributed to the different mobilization protocol for the patients who received cups with impaction grafting. Immobilization is associated with lower dislocation rates.[21] The overall dislocation rate in our study was 11.4%, which is relatively high. However, subluxation rates in young patients having THA have been reported to be as much as 18.2%.[14] The overall complication rate of 17% (30 postoperative complications) is also relatively high. Joshi et al.[18] reported a complication rate of 11.5% in cemented hips and Duffy et al.[15] reported a complication rate of 12% during the perioperative period.

As expected, revised and radiographically loose cups showed more polyethylene wear. This is consistent with previous reports showing wear particles are associated with osteolysis in THA. The average wear rate of the cups of 0.08 mm/year is within the normal limits, keeping in mind that wear in younger patients can be 33% to 40% higher than wear in older patients.[27] In a large study of 226 hips in patients younger than 40 years with a Charnley® prosthesis, Sochart and Porter[33] reported an average wear rate of 0.08 to 0.10 mm/year in the nonrevised cups, which is comparable to our results. Wan et al.[37] found a correlation between inclination of the cup and higher/lower wear rates. However, we did not observe higher wear with abnormal position or inner cup diameter.

The observed overall midterm survival of cemented polyethylene cups in patients younger than 40 years in our study was acceptable. Especially in these young patients, there is a need for total hip implants with proven long-term survival.[20] Although the use of uncemented prostheses in these young patients is very popular, literature regarding long-term outcome of THA in patients younger than 40 years concerns mainly studies of cemented implants and less about uncemented implants (Table 8).[5,8,9,15,18,20,25,32-34] A limitation of the reported midterm or long-term results of uncemented cups is the fact that in these studies first generation uncemented cups were used. The long-term outcome of improved newer uncemented cup designs remains unclear. Most of these older cup designs no longer are available. The only report of uncemented cups at 15 years after surgery with an end point of revision for any reason showed a survival rate of 54%.[20] This is less favorable than the results of cemented cups at that time (Table 8). Sochart and Porter[34] had survival rates of 71% and 68% at 20 and 25 years, respectively, for cemented Charnley® cups. The survival of the acetabular uncemented cups with an end point of revision for aseptic loosening in patients younger than 40 years reported in one study was 85%,[15] in contrast to a survival rate of 96% after 10 years of the Charnley® cups in the study by Joshi et al..[18] We found a survival rate with cemented cups of 92% at 10 years with an end point of revision for aseptic loosening.

A remarkable finding of our study was the survival of cups with acetabular reconstructions with impaction grafting was at least comparable to the survival of standard cemented cups, especially considering the more difficult hips of our study population needed reconstruction with impaction grafting. Our data on the cemented cups with impaction grafting showed similar survival, where rather lower survival rates

would be expected. The outcome of these cups reconstructed with impaction grafting even fulfilled the NICE criteria (a survival of > 90% after 10 years),[23] with a survival rate of 91% at 10 years with an end point of revision for any reason. The survival rates of the cemented cups in our study are comparable to those reported for cemented cups.[8,18,34] Although cemented cups are not commonly used in young patients, our data suggest cemented conventional polyethylene cups are still a good option in THA in young patients. Even reconstruction of (severe) acetabular deficiencies with impaction grafting and a cemented conventional polyethylene cup produced very acceptable survival rates, comparable to the rates of cemented cups implanted in acetabuli without deficiencies with standard cementing techniques.

Table 8. Long-term acetabular cup survival rates in patients younger than 40 years in the published literature until December 2007.

Study	Number of hips	Age (years)*	Followup (years)*	Type of cup	Survival†						
					5 years	7 years	10 years	15 years	20 years	25 years	30 years
Uncemented											
Bizot et al.[5]	87	32.3 (17–40)	7.7 (0–19)‡	Screw-in alumina insert	94.7 (68.5–99.2)	88.8 (62.0–97.1)	88.8 (62.0–97.1)				
				Cerapress alumina	100	95.1 (69.8–99.3)					
				Cerafit alumina	100	94.3 (66.3–99.2)					
Duffy et al.[15]	82	32 (17–39)	10.3 (10–14)	PCA, Osteonics, H-G porous			Aseptic: 84.6 (76–93) Excl inf: 81.8 (73–91)				
McAuley et al.[20]	256	33.2 (16–40)	7.3 (0–19)	Duraloc, AML, Arthropor, Triloc, H-G, Solution	97.4 (SE 2.2)		87.6 (SE 6.0)	53.8 (SE 13.9)			
Odent et al.[25]	62	18.3 (11.8–31)	6 (3–13)	Zweymuller			90.1 (SE 7.1)				
Cemented											
Bizot et al.[5]	41	32.3 (17–40)	7.7 (0–19)‡	Plain alumina	97.3 (81.9–99.6)	94.1 (78.1–98.5)	90.4 (73.0–96.8)	78.9 (54.7–91.1)			
Chiu et al.[8]	47§	28.8 (17–39)	14.9 (7–21)	Charnley polyethylene			86.3 (75.5–97.1)	27.0 (10.7–43.3)			
Chmell et al.[9]	66	19.9 (11–29)	15.1 (11–22)	Trapezoidal, Aufranc-Turner, custom-made	Aseptic: 98 (SE 1.6)	Aseptic: 97 (SE 2.8)	Aseptic: 84.5 (SE 4.7)	Aseptic: 70 (SE 7.3)	Aseptic: 40 (SE 15.6)		
Joshi et al.[18]	218	32 (17–39)	16 (10–24)	Charnley polyethylene	Aseptic: 99 (SE 0.5)		Aseptic: 96 (SE 1.4)	Aseptic: 91 (SE 2.3)	Aseptic: 84 (SE 4.6)		
Sochart and Porter[34]	226	31.7 (17–39)	19.7 (2–30)	Charnley polyethylene			93 (90–96)		71 (65–77)	68 (61–75)	
Sochart and Porter[33]	83	24.9 (17–29)	20 (5.2–30)	Charnley			92 (85–98)		70 (60–81)	68 (57–79)	
Sochart and Porter[32]	43	28.8 (19–39)	22.4 (0.1–30.3)	Charnley					73 (61–84)		70 (57–83)
Current study	175	31.0 (16–39)	8.1 (2.0–18.5)	Exeter, Charnley, Müller/AlloPro			85 (78–92)				
							Aseptic: 92 (87–98)				
				With impacted bone grafts			91 (83–99)				
							Aseptic: 95 (89–100)				

*Values are expressed as mean, with range in parentheses; †values are expressed as percentage, with 95% confidence interval in parentheses; ‡deceased and revised excluded; §lost to followup, deceased excluded, only Chinese patients; AML = anatomic medullary locking; PCA = porous-coated anatomic; Excl inf = excluding infections; H-G = Harris-Galante; SE = standard error.

References

1. Australian Orthopaedic Association. National Joint Replacement Registry; Annual Report 2007. Available at: http://www.aoa.org.au/docs/njarep07.pdf. Accessed December 2008.
2. Beaulé PE, Dorey FJ, Hoke R, LeDuff M, Amstutz HC. The value of patient activity level in the outcome of total hip arthroplasty. *J Arthroplast.* 2006;21:547-552.
3. Berbari EF, Hanssen AD, Duffy MC, Steckelberg JM, Ilstrup DM, Harmsen WS, Osmon DR. Risk factors for prosthetic joint infection: case-control study. *Clin Infect Dis* 1998;27:1247-1254.
4. Berbari EF, Osmon DR, Duffy MC, Harmssen RN, Mandrekar JN, Hanssen AD, Steckelberg JM. Outcome of prosthetic joint infection in patients with rheumatoid arthritis: the impact of medical and surgical therapy in 200 episodes. *Clin Infect Dis* 2006;42:216-223.
5. Bizot P, Banallec L, Sedel L, Nizard R. Alumina-on-alumina total hip prostheses in patients 40 years of age or younger. *Clin Orthop Relat Res* 2000;379:68-76.
6. Brooker AF, Bowerman JW, Robinson RA, Riley LH. Ectopic ossification following Total hip replacement: Incidence and a method of classification. *J Bone Joint Surg Am* 1973;55:1629-1632.
7. Charnley J. The long-term results of low-friction arthroplasty of the hip performed as a primary intervention. *J Bone Joint Surg Br* 1972;54:61-76.
8. Chiu KY, Ng TP, Tang WM, Poon KC, Ho WY, Yip D. Charnley total hip arthroplasty in Chinese patients less than 40 years old. *J Arthroplasty* 2001;16:92-101.
9. Chmell MJ, Scott RD, Thomas WH, Sledge CB. Total hip arthroplasty with cement for juvenile rheumatoid arthritis: results at a minimum of ten years in patients less than thirty years old. *J Bone Joint Surg Am* 997;79:44-52.
10. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF. Classification and management of acetabular abnormalities in total hip arthroplasty. *Clin Orthop Relat Res* 1989;243:126-137.
11. Dawson J, Carr A, Murray D. Questionnaire on the perceptions of patients about Total hip replacement. *J Bone Joint Surg Br* 1996;78:185-190.
12. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976;121:20-32.
13. Dorr LD, Wan Z. Comparative results of a distal modular sleeve, circumferential coating, and stiffness relief using the Anatomic Porous Replacement II. *J Arthroplasty* 1996;11:419-428.
14. Dudkiewicz I, Salai M, Blankstein A, Chechik A. Total hip arthroplasty in patients younger than 30 years of age following developmental dysplasia of hip (DDH) in infancy. *Arch Orthop Trauma Surg* 2002;122:139-142.
15. Duffy GP, Berry DJ, Rowland C, Cabanela ME. Primary uncemented total hip arthroplasty in patients < 40 years old: 10- to 14-year results using first-generation proximally porous-coated implants. *J Arthroplasty* 2001;16:140-144.
16. Goodman SB, Adler SJ, Fyhrie DP, Schurman DJ. The acetabular teardrop and its relevance to acetabular migration. *Clin Orthop Relat Res* 1988;236:199-204.
17. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 1969;51:737-755.
18. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC. Long-term results of Charnley lowfriction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75:616-623.
19. Kobayashi S, Eftekhar NS, Terayama K, Joshi RP. Comparative study of total hip arthroplasty between younger and older patients. *Clin Orthop Relat Res* 1997;339:140-151.
20. McAuley JP, Szuszczewicz ES, Young A, Engh CA Sr. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-125.
21. Morrey BF. Difficult complications after hip joint replacement: dislocation. *Clin Orthop Relat Res* 1997;344:179-187.
22. Murray DW, Britton AR, Bulstrode CJ. Loss to follow-up matters. *J Bone Joint Surg Br* 1997;79:254-257.
23. National Institute for Clinical Excellence (NICE). Guidance on the Selection of Prostheses for Primary Hip Replacement. London, UK: NICE; 2003.
24. Norwegian Arthroplasty Register. Annual Report 2007. Available at: http://www.haukeland.no/nrl/Report2007.pdf. Accessed December 2008.
25. Odent T, Journeau P, Prieur A, Touzet P, Pouliquen J. Cementless hip arthroplasty in juvenile idiopathic arthritis. *J Pediatr Orthop* 2005;25:465-470.
26. Salvati EA, Chuem V, Aglietti P, Wilson PD. Radiology of total hip replacements. *Clin Orthop Relat Res* 1976;121:74-82.
27. Schmalzried TP, Huk OL. Patient factors and wear in total hip arthroplasty. *Clin Orthop Relat Res* 2004;418:94-97.
28. Schreurs BW, Busch VJ, Welten ML, Verdonschot N, Slooff TJ. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86:2385-2392.
29. Schreurs BW, Slooff TJ, Gardeniers JW, Buma P. Acetabular reconstruction with bone impaction grafting and a cemented cup: 20 years' experience. *Clin Orthop Relat Res* 2001;393:202-215.
30. Schreurs BW, Van Tienen TG, Buma P, Verdonschot N, Gardeniers JW. Favorable results of acetabular reconstruction with impacted morsellized bone grafts in patients younger than 50 years: a 10- to 18-year follow-up study of 34 cemented total hip arthroplasties. *Acta Orthop Scand* 2001;72:120-126.
31. Sechriest VF 2nd, Kyle RF, Marek DJ, Spates JD, Saleh KJ, Kuskowski M. Activity level in young patients with primary total hip arthroplasty: a 5-year minimum follow-up. *J Arthroplasty* 2007;22:39-47.

32. Sochart DH, Porter ML. Long-term results of total hip replacement in young patients who had ankylosing spondylitis: eighteen to thirty-year results with survivorship analysis. *J Bone Joint Surg Am* 1997;79:1181-1189.
33. Sochart DH, Porter ML. The long-term results of Charnley low-friction arthroplasty in young patients who have congenital dislocation, degenerative osteoarthritis, or rheumatoid arthritis. *J Bone Joint Surg Am* 1997;79:1599-1617.
34. Sochart DH, Porter ML. Long-term results of Charnley low-friction arthroplasty in patients aged less than 30 years. *J Arthroplasty* 1998;13:123-131.
35. Swedish Hip Arthroplasty Register. Annual Report 2006. Available at: http://www.jru.orthop.gu.se. Accessed December 2008.
36. Van den Donk S, Buma P, Slooff TJ, Gardeniers JW, Schreurs BW. Incorporation of morselized bone grafts: a study of 24 acetabular biopsy specimens. *Clin Orthop Relat Res* 2002;396:131-141.
37. Wan Z, Boutary M, Dorr LD. The influence of acetabular component position on wear in total hip arthroplasty. *J Arthroplasty* 2008;23:51-56.
38. Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *J Arthroplasty* 1998;13:890-895.

Chapter 5

Een heupprothese met cement bij patiënten jonger dan 40 jaar en reconstructie van eventuele botdefecten met botsnippers

D.C.J. de Kam
J.W.M. Gardeniers
R.P.H. Veth
B.W. Schreurs

Nederlands Tijdschrift voor de Geneeskunde 2010;154:A811.

Samenvatting

Doel. Bepalen van de langetermijnresultaten van primaire gecementeerde totaleheupprothesen bij patiënten die ten tijde van de operatie jonger dan 40 jaar zijn. In geval van een botdefect aan komzijde werd deze eerst gereconstrueerd met geïmpacteerde botsnippers voor het plaatsen van een gecementeerde cup.

Opzet. Analyse van een vervolgde patiënten cohort.

Methode. Analyse vond plaats van patiëntengegevens die tussen 1 januari 1988 en 30 juni 2004 een primaire gecementeerde totaleheupprothese kregen en een leeftijd hadden van 40 jaar of jonger. Hoofddoel was het bepalen van de tijd tot revisie. De overleving werd berekend met Kaplan-Meiermethode.

Resultaten. In totaal werden 175 heupprothesen bij 130 patiënten geïncludeerd. Acetabulaire reconstructie met geïmpacteerde botsnippers werd verricht in 84 heupen (48%). De gemiddelde leeftijd bij operatie was 31 jaar. Zes patiënten zijn overleden tijdens follow-up (8 heupen), niemand hiervan heeft een revisie gehad. De gemiddelde follow-up was 8,1 (uitersten 2,0-18,5) jaar. Er zijn 24 heupen (14%) gereviseerd. Redenen voor revisie waren: septische loslating (8), recidiverende luxaties (4), traumatische loslating (1) en aseptische loslating (11). De overleving na 10 jaar was 83% (95%B.I. 76-90%). De aseptische overleving was 92% (95%B.I. 86-98%). Aseptische overleving van de cups met en zonder BIG was respectievelijk 95% (95%B.I. 89-100%) en 90% (95%B.I. 81-99%) (p=0,73)

Conclusie. Vervanging van het heupgewricht bij patiënten onder de 40 jaar door een gecementeerde totaleheupprothese laat goede langetermijnresultaten zien. Acetabulaire botdefecten gereconstrueerd met geïmpacteerde botsnippers bij deze patiëntengroep laten goede resultaten zien.

Abstract
A Total hip arthroplasty with cement in patients under 40 years of age and if indicated, a reconstruction with impaction grafting of bone defects.

Objective. To determine the long-term results of primary cemented total hip arthroplasty in patients under the age of 40 at index surgery. In case of acetabular deficiency, a reconstruction with bone impaction grafting was performed first before a cemented cup was implanted.

Design. Analysis of a followed patient cohort.

Methods. All clinical data and radiographs were analysed of patients who received a primary cemented total hip arthroplasty under the age of 40, between 1 January 1988 and 30 June 2004. The main goal of this study was to determine the survival with endpoint revision, using Kaplan Meier analysis.

Results. 175 consecutive total hip arthroplasties were implanted in 130 patients. Bone impaction grafting was performed in 84 patients (48%). The average age at index surgery was 31 years. Six patients (8 hips) died during follow-up. None were revised. Mean follow-up was 8,1 (range 2,0-18,5) years. In total, 24 hips (14%) were revised. Reasons for revision were: septic loosening (8), recurrent dislocations (4), traumatic loosening (1) and aseptic loosening (11). The 10-years survival was 83% (95%C.I. 76-90%) with endpoint revision for any reason and 92% (95%C.I. 86-98%) with endpoint revision for aseptic loosening. Aseptic survival of the cups with and without bone impaction grafting was respectively 95% (95%C.I. 89-100%) and 90% (95%C.I. 81-99%) (p=0,73).

Conclusion. Hip replacement with cemented total hip arthroplasty in patients under the age of 40 shows good long-term results. Acetabular deficiencies reconstructed with impacted bone grafts in these patients show good results.

Het plaatsen van een totaleheupprothese bij arthrose van de heup wordt al meer dan 50 jaar uitgevoerd. In Nederland worden jaarlijks bijna 21.000 totaleheupprothesen geplaatst. Hoewel slechts een klein aantal van deze heupprothesen wordt geïmplanteerd bij patiënten jonger dan 40 jaar, is er wel een groot probleem met de overleving van deze heupprothesen.

Bij jonge patiënten kunnen verschillende soorten heupprothesen worden gebruikt, er zijn 2 grote groepen te onderscheiden: gecementeerd en ongecementeerd. De overleving van gecementeerde prothesen bij jonge patiënten is helaas slechter in vergelijking met de overleving van totaleheupprothesen in de normale, oudere patiëntenpopulatie.[1-3] Als oplossing zijn prothesen met een alternatieve fixatie techniek ontwikkeld, de ongecementeerde prothesen (gebaseerd op botingroei). In sommige landen is dit het enige type heupprothese die gebruikt wordt bij jonge patiënten. Echter, literatuuronderzoek heeft aangetoond dat de langetermijnresultaten van ongecementeerde totaleheupprothesen geen verbetering laten ten opzichte van gecementeerde heupprothesen bij patiënten onder de 50 jaar.[4]

Waar primaire coxarthrose de meest gestelde diagnose is bij de oudere patiënten, is secundaire coxarthrose op basis van een onderliggende heupafwijking de meest voorkomende indicatie voor een totaleheupprothese bij jonge patiënten. Deze onderliggende aandoeningen gaan vaak gepaard met (fors) botverlies, vooral aan de kom (acetabulaire) zijde. Dit maakt de implantatie van een totaleheupprothese in deze specifieke groep lastig en draagt bij aan de teleurstellende resultaten.
In het Universitair Medisch Centrum St Radboud te Nijmegen worden deze acetabulaire defecten al ruim 20 jaar gereconstrueerd met geïmpacteerde botsnippers, zowel bij jongere als oudere patiënten.[5,6]

Onze primaire hypothese is dat gecementeerde heupprothesen bij jonge patiënten een goede optie zijn met een goede overleving van de prothese, maar wel moeten komdefecten, als deze er zijn, op biologische wijze worden gereconstrueerd. Secundair doel van deze studie is het rapporteren van klinische resultaten en complicaties van deze populatie.

Methode

Onderzoeksopzet

Alle patiënten die in onze kliniek in de periode van januari 1988 tot en met juni 2004 onder de leeftijd van 40 jaar een primaire gecementeerde totaleheupprothese hebben gekregen zijn geïncludeerd. De minimale follow-up bedroeg 2 jaar, hierdoor weten wij zeker dat alle heupen minimaal 1 tot 1,5 jaar maximaal belast zijn. Geen enkele patiënt werd geëxcludeerd. Analyse vond plaats van alle verzamelde klinische, poliklinische en radiologische follow-up gegevens. Patiënten die meer dan 2 jaar niet op controle waren geweest werden opgeroepen ter evaluatie.

Operatietechniek

Na resectie van de heupkop werd het acetabulum geprepareerd. Als er geen botdefect aan de komzijde was werd direct een polyethyleen cup gecementeerd. Indien er wel een botdefect aanwezig was, werd dit defect ingeschaald volgens de classificatie van de American Academy of Orthopaedic Surgeons (Tabel 1).[7] Bij acetabulaire defecten werden

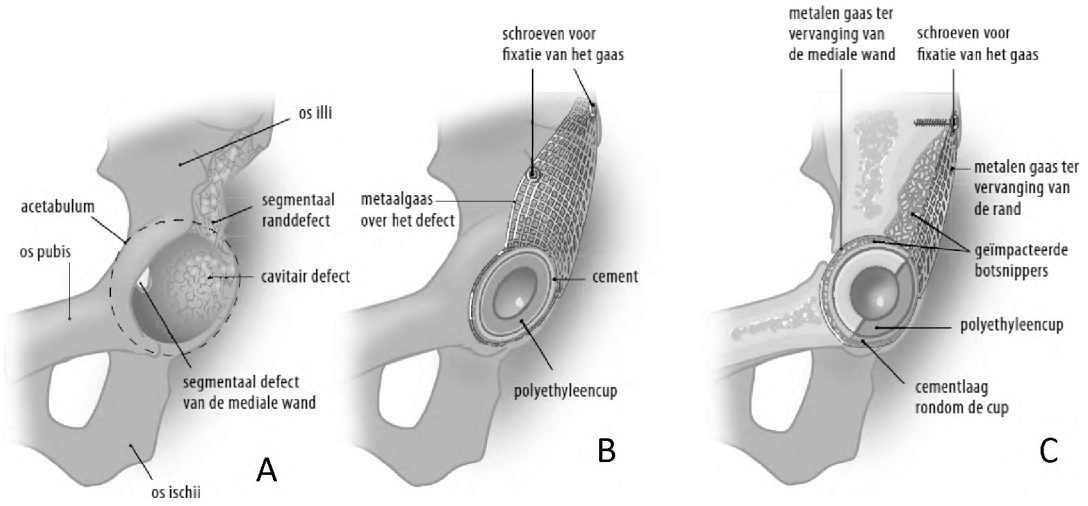
Tabel 1. Classificatie van acetabulaire botdefecten volgens de American Academy of Orthopaedic Surgeons.[7]

Type		Defect omschrijving
Type I	Segmentaal defect	Het ontbreken van wand of rand. Dit kan perifeer (superieure, anterieure en/of posterieure rand) en/of centraal (afwezigheid van mediale wand) zijn.
Type II	Cavitair defect	De wand of rand staat nog wel, echter er is sprake van een volumemetrisch defect. Ook hier onderscheid tussen perifeer en centraal
Type III	Gecombineerd defect	Er is sprake van zowel een segmentaal als een perifeer defect.
Type IV	Bekken discontinuïteit	De voorste of achterste pijler van het acetabulum is onderbroken of afwezig waardoor er geen continuïteit van het acetabulum is.
Type V	Arthrodese	Benige verbinding tussen acetabulum en femur.

wanddefecten (segmentale defecten) eerst gereconstrueerd met metaalgazen. Vervolgens werden botsnippers in het defect gelegd, welke daarna met speciaal instrumentarium stevig werden geïmpacteerd, zodat het defect opgevuld wordt met een stevige bodem bottransplantaat (Figuur 1). Tenslotte werd een standaard polyethyleencup gecementeerd. Als bron voor de botsnippers werd meestal de eigen heupkop gebruikt, soms waren één of meerdere donor heupkoppen uit de botbank nodig om het defect geheel op te vullen. Deze techniek is eerder in dit tijdschrift uitgebreid beschreven.[8-9] Femoraal werd ook op gestandaardiseerde wijze altijd een gecementeerde steel geplaatst. Gebruikte prothesen waren: Exeter (Stryker-Howmedica, Newbury, Groot-Brittannië), Charnley (DePuy, Leeds, Groot-Brittannië) en Müller (Sulzer, Winterthur, Zwitserland). Alle patiënten kregen preoperatief antibiotische profylaxe tegen infecties.

Nabehandeling
Patiënten zonder acetabulaire reconstructie werden 1 tot 2 dagen postoperatief gemobiliseerd onder leiding van een fysiotherapeut. Volledig belasten was toegestaan vanaf 6 weken na de operatie. In geval van een kom reconstructie met botsnippers was in de eerste 6 weken 10% belasten toegestaan. In de 6 daaropvolgende weken werd dit uitgebreid tot 50%, na 12 weken werd volledig belasten toegestaan. Patiënten met een uitgebreide acetabulaire reconstructie en patiënten met een reconstructie geopereerd voor 1990 kregen soms eerst een periode van bedrust van enkele dagen tot maximaal 6 weken voorgeschreven. Alle patiënten ontvingen postoperatief een trombose profylaxe en een profylaxe voor het tegengaan van periarticulaire ossificaties.

Follow-up
Patiënten werden postoperatief klinisch en radiologisch vervolgd na 6 weken, 3, 6, 9, 12 maanden en daarna jaarlijks of tweejaarlijks. Poliklinisch werden vragenlijsten afgenomen: de 'Harris Hip Score' (HHS), de 'Oxford Hip Questionnaire Score' (OHQS) en Visual Analoque Scales (VAS) betreffende pijn en tevredenheid. De Harris Hip Score en



Figuur 1A-C. Reconstructie van een acetabulum defect met geïmpacteerde botsnippers: (a) Weergave van acetabulair defect met een segmentaal defect van de mediale wand en craniale rand; (b) status na reconstructie en plaatsen van de cup; (c) dwarsdoorsnede van de opbouw met reconstructie van de mediale wand en craniale rand met metaalgazen waarop de botsnippers worden geïmpacteerd, hierop wordt een cementeerde cup geplaatst.

de Oxford Hip Questionnaire Score zijn internationaal gebruikte vragenlijsten die ingaan op pijn, functionaliteit, hulpmiddelen, loopafstand en mank lopen. De meest recente klinische en radiologische gegevens werden gebruikt bij de evaluatie. Helaas waren niet van alle patiënten alle vragenlijsten te achterhalen, het aantal beschikbare vragenlijsten is weergegeven bij de resultaten. Eindpunt van follow-up was het verwijderen of reviseren van één of meerdere onderdelen van de totale heupprothese (kom, steel en/of kopje).

Statistische analyse
De overleving van de totaleheupprothesen werd met behulp van de Kaplan-Meier methode berekend. Eindpunten voor analyse waren: revisie voor alle redenen, alle revisies uitgezonderd de revisies wegens infectie en alle revisies wegens aseptische (mechanische) loslating. Met overleving wordt de periode bedoeld dat de totaleheupprothese niet is verwijderd of gereviseerd. Statistische verschillen werden berekend met de Log-rank test of de Student t-test.

Resultaten

Tijdens de onderzoeksperiode zijn 175 primaire gecementeerde totaleheupprothesen bij 130 patiënten onder de 40 jaar geplaatst. De gemiddelde leeftijd ten tijde van de operatie was 31,3 jaar (uitersten 16-39). Demografische gegevens en onderliggende diagnosen zijn weergegeven in Tabel 2.

Tijdens follow-up zijn 6 patiënten (8 heupen) overleden aan oorzaken niet gerelateerd aan de operatie of prothese. De gemiddelde follow-up, inclusief overleden en gereviseerde patiënten, bedroeg 8,1 jaar (uitersten 2,0-18,5).

In totaal hadden 86 van de 175 heupen (49%) een kom defect ten gevolge van hun onderliggende aandoening (Tabel 2). Van alle defecten zijn er 84 gereconstrueerd met geïmpacteerde botsnippers. Bij 2 heupen werd er afgeweken van het protocol en werd er een acetabulaire reconstructie verricht met een solide bottransplantaat.

Berekende overleving van de prothese
De overleving van de prothese na 10 jaar met als eindpunt revisie voor welke reden dan ook was 83% (95% B.I. 76-90%) (Kaplan-Meier)(Figuur 2A, tabel 3). Na uitsluiting van revisies wegens infectie was 89% (95%B.I. 83-95%) revisievrij na 10 jaar. De overleving van alle heupprothesen met eindpunt revisie voor aseptische (mechanische) loslating was 92% (95%B.I. 86-98%) na 10 jaar (Figuur 2B). Analyse van alle stelen met als eindpunt revisie wegens aseptische steelloslating liet een overleving van de prothese zien van 98% (95%B.I. 96-100%) na 10 jaar. De cups hadden een revisie vrije overleving van 92% (95%B.I. 87-98%) na 10 jaar als men kijkt naar de aseptische cuploslatingen. De cups zonder bottransplantaat en cups met bottransplantaat lieten een overleving van de prothese zien van 90% (95%B.I. 81-99%) en 95% (95%B.I. 89-100) na 10 jaar met als eindpunt revisie voor aseptische loslating. Aangaande de tijd tot aseptische loslating is het verschil tussen de groepen met en zonder bottransplantaat niet statistisch significant (Log-Rank, p=0,73). Ter vergelijking vonden we middels Cox regressie dat de hazard ratio van de cups met bottransplantaat 0,80 (95%B.I. 0,22-2,87; p=0,73) is. Hierbij dient wel vermeldt te worden dat het maar de vraag is of aan de voorwaarde voor Cox-regressie voldaan is (Figuur 2C).

Klinische vragenlijsten
Van de patiënten die geen revisie hadden ondergaan (151 heupen) zijn de klinische scoringslijsten geanalyseerd. De mediane preoperatieve HHS was 50 (gemiddeld 49,4; uitersten 15-82; n=94), op een schaal van 100 (goed) tot 0 (slecht). De mediane HHS verbeterde postoperatief naar 94 (gemiddelde 88,0; uitersten 12-100; n=137). De mediane OHQS was 38 (gemiddeld 39,1; uitersten 12-52; n=23) preoperatief, op een

Tabel 2. Demografische gegevens en karakteristieken van alle patiënten.

Item	Aantal
Aantal patiënten	130
Aantal totaleheupprothesen	175
Overleden	
Aantal patiënten	6
Aantal heupen	8
Aantal patiënten zoekgeraakt tijdens follow-up	0
Leeftijd ten tijde van operatie	
Gemiddeld	31,3
Uitersten	16-39
Follow-up	
Gemiddeld	8,1
Uitersten	2,0-18,5
Geslacht	
Man	55
Vrouw	75
Zijde	
Links	89
Rechts	86
Bilateraal	45
Aantal patiënten met een acetabulair defect	86
Type I	16
Type II	39
Type III	29
Type IV	0
Type V	2
Acetabulaire reconstructie met botsnippers	
Ja	84
Nee	91
Indicaties	
Congenitale heupdysplasie	42
Corticosteroïden geïnduceerde avasculaire kopnecrose	39
Reumatoïde artritis	27
Ziekte van Perthes	9
Avasculaire kopnecrose eci	8
Epifysaire dysplasie	7
Posttraumatische artrose	6
Overige	37
Complicaties	
Peroperatief	9
Postoperatief	30
Postoperatief waarvoor chirurgische interventie (geen revisie)	7
Revisies	24

schaal van 12 (goed) tot 60 (slecht). Deze verbeterde naar een mediaan van 16 punten (gemiddelde 18,7; uitersten 12-45; n=135). De mediane VAS voor pijn tijdens rust op een schaal van 0 (geen pijn) tot 100 (ondragelijke pijn) was postoperatief 0 (gemiddelde 7,4; uitersten 0-75). De VAS voor pijn tijdens inspanning had postoperatief een mediaan van 4 (gemiddelde 18,7; uitersten 0-100). De mediane VAS voor tevredenheid (0 is niet tevreden, 100 is tevreden) was postoperatief 90 (gemiddelde 86,2; uitersten 0-100).

Revisies

Van de 175 heupen zijn er 24 gereviseerd (14%). Acht heupen (4,6%) ondergingen revisie wegens een infectie. De gemiddelde tijd tot revisie bedroeg 5,3 jaar (uitersten 2,2-8,1). Eén heup zat septisch los binnen 2 jaar, deze infectie kan gerelateerd worden aan de operatie. De overige infecties worden beschouwd als een acute hematogene infectie van een goed functionerende prothese.

Tabel 3. Aantal patiënten resterend en gereviseerd gedurende de follow-up.

Follow-up (jaren)	Aantal patiënten resterend	Gereviseerd (totaal)
0	175	0
1	172	2
2	169	3
3	158	6
4	137	10
5	120	12
6	106	14
7	92	16
8	81	17
9	70	19
10	50	21
11	43	22
12	31	22
13	24	22
14	24	22
15	20	22
16	15	22
17	8	24
18	2	24
19	0	24

Ten gevolge van recidiverende luxaties zijn 4 heupen (2,3%) gereviseerd. Eén heup (0,6%) zat los na een trauma, beide onderdelen werden gereviseerd na 10,3 jaar goed gefunctioneerd te hebben. Elf heupen (6,6%) zijn gereviseerd wegens mechanische/aseptische loslating. In 2 gevallen zat zowel de steel als de cup los na 6,4 en 16,2 jaar. Eén steel is gereviseerd na 2,7 jaar wegens aseptische loslating. In 8 heupen moest er een cuprevisie plaatsvinden voor aseptische loslating. Dit gebeurde na gemiddeld 6,0 jaar (uitersten 1,1-16,8). Van alle 10 cups die gereviseerd waren, hadden 4 cups een reconstructie gehad met geïmpacteerde botsnippers en 6 cups hadden geen reconstructie nodig. De gemiddelde tijd tot revisie voor de cups met en zonder reconstructie waren respectievelijk 11,7 jaar (uitersten 4,1-16,8) en 4,0 jaar (uitersten 1,1-10,0), dit verschil is significant (p=0,032).

Complicaties

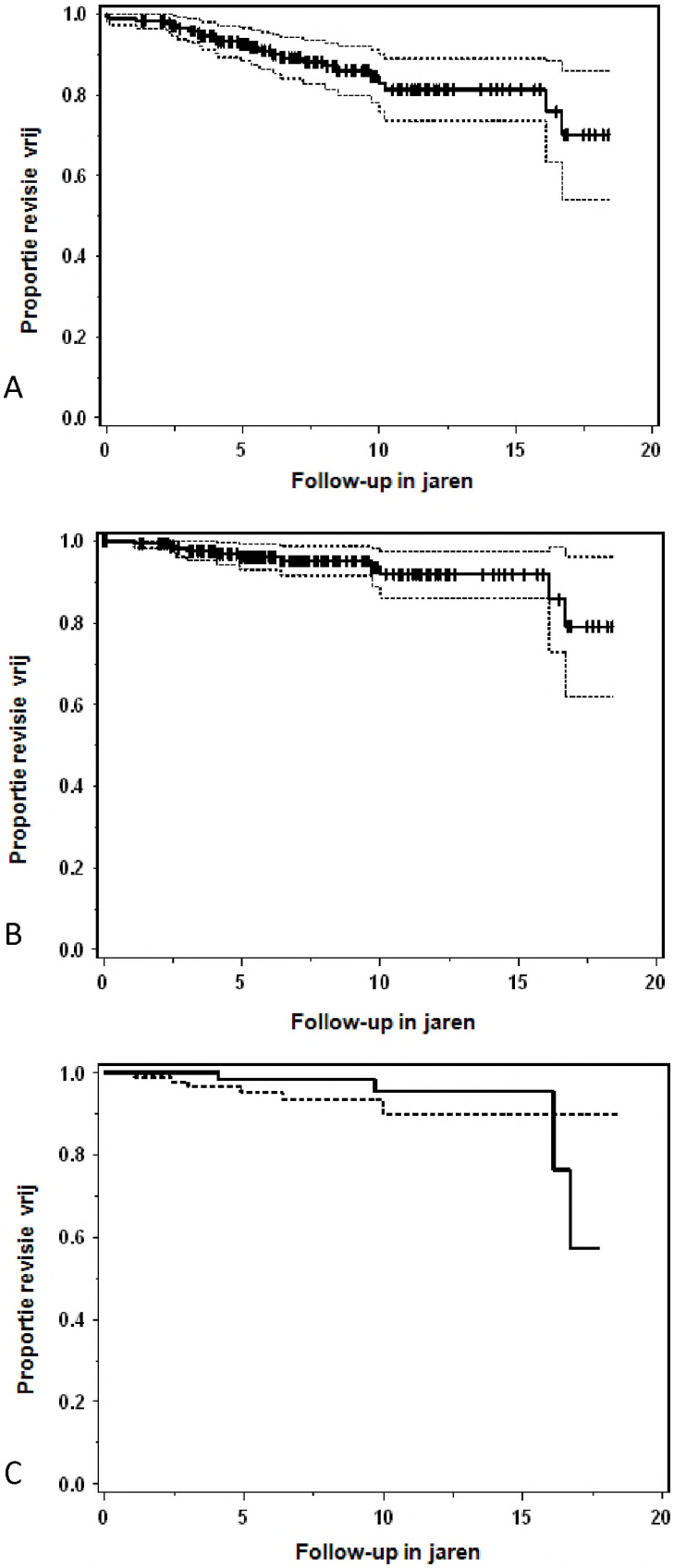
Er zijn 9 peroperatieve complicaties opgetreden, 30 postoperatieve complicaties en 7 postoperatieve complicaties waarbij chirurgisch ingrijpen noodzakelijk was (met uitzondering van de complicaties die revisie als gevolg hadden). De meest voorkomende complicaties waren luxaties (n=15) en hematoomvorming (n=6).

Beschouwing

Deze studie laat zien dat gecementeerde totaleheupprothesen bij jonge patiënten bevredigende resultaten geven. Naar onze mening moeten eventuele botdefecten aan de komzijde worden hersteld met behulp van geïmpacteerde botsnippers. Het is vervolgens opvallend dat de totale heupprothesen waarbij een acetabulaire reconstructie noodzakelijk was even goed presteren als zonder reconstructie. Deze biologische reconstructie techniek is dus aantrekkelijk om technisch lastige casus te behandelen.

Overleving in de literatuur

Volgens de NICE-criteria mag men van een goede prothese verwachten dat de overleving na 10 jaar minimaal 90% is.[10] De 10-jaars resultaten van gecementeerde totaleheupprothesen bij patiënten onder de 40 jaar die gepubliceerd zijn variëren van 73 tot 93%, met als eindpunt revisie voor welke reden dan ook.[11-17] De gepubliceerde resultaten van ongecementeerde totaleheupprothesen bij jonge patiënten variëren van 67 tot 85%.[18-20] Er zijn dus geen resultaten gepubliceerd van ongecementeerde



Figuur 2A-C. Kaplan-Meier survival analyses van: (A) Alle totaleheupprothesen met als eindpunt revisie voor welke reden dan ook; (B) alle heupprothesen met als eindpunt revisie wegens aseptische loslating; (C) de cups met reconstructie met botsnippers (solide lijn) en cups zonder reconstructie (onderbroken lijn).

totaleheupprothesen bij patiënten onder de 40 jaar met een overleving van 90% of meer na 10 jaar. Dit is opvallend omdat uit de gegevens van het Zweedse heupregister (www.jru.orthop.gu.se) blijkt dat het gebruik van ongecementeerde heupprothesen bij jonge patiënten juist toeneemt.

De overleving van de totaleheupprothese in onze studie met eindpunt revisie voor welke reden dan ook was 83% na 10 jaar en de aseptische overleving van de stelen en cups waren 98% en 92% na 10 jaar. Deze resultaten zijn vergelijkbaar met die van de gepubliceerde gegevens van de gecementeerde Charnley prothesen, welke toch als de prothesen met de beste lange termijn resultaten worden beschouwd.[11-14,17]

De zwakste schakel

Uit de meeste studies blijkt dat de acetabulaire cup de zwakste schakel is van een totaleheupprothese. De revisiepercentages van de cups zijn doorgaans hoger dan die van de stelen.[12-20] Er zijn geen studies bekend waarbij de ongecementeerde cups een overleving hadden die voldeed aan de NICE-criteria, dit in tegenstelling tot studies met gecementeerde cups.[11,12,17] De cups in deze studie die een acetabulaire reconstructie hebben gehad met geïmpacteerde botsnippers lijken het beter te doen dan de cups zonder een bottransplantaat, met een overleving van 91% tegenover 79% (aseptisch: 95% tegenover 90%) na 10 jaar.

Het herstellen van acetabulaire defecten met geïmpacteerde botsnippers is geen eenvoudige techniek. Het reconstrueren van acetabulaire defecten met geïmpacteerde botsnippers is vooral een aantrekkelijke operatietechniek bij jonge patiënten. Immers, de onderliggende heupaandoeningen bij deze patiënten die verantwoordelijk zijn voor het optreden van arthrose op jonge leeftijd gaan vaak gepaard met fors acetabulair botverlies. Bij deze jonge patiënten valt in de toekomst zeker een revisie te verwachten als men kijkt naar de levensduur van een totaleheupprothese. Het lijkt aantrekkelijk om juist bij deze patiënten een biologische reconstructie van de al aanwezige botdefecten te verrichten, in plaats van het botdefect op te vullen met cement of een grotere aangepaste cup. Dit om een heuprevisie in de toekomst beter mogelijk te maken.

Sterke en zwakke punten

De patiënten in deze studie zijn door verschillende ervaren chirurgen geopereerd in het UMC St. Radboud met een gestandaardiseerd behandelingsprotocol. Alle onderliggende diagnoses zijn geïncludeerd, geen enkele patiënt is geëxcludeerd. Alle patiënten kregen een volledig gecementeerde prothese en in geval van een acetabulair defect werd deze altijd met een bottransplantaat gereconstrueerd. Dit betekent dat er geen selectiebias is betreffende de keuze van operatie techniek. Ook waren alle gegevens van alle patiënten beschikbaar voor analyse (met uitzondering van 1 recente röntgenfoto van 1 patiënt) waardoor het onderzoek als compleet en betrouwbaar mag worden beschouwd. Echter een deel van de vragenlijsten ontbrak, mede doordat de OHQS pas later in onze kliniek is geïntroduceerd en het niet gestructureerd afnemen van de vragenlijsten vroeger. Daarentegen, zien wij dat al de patiënten waarbij het misgaat in onze kliniek blijven voor een eventuele revisie, dus de uitkomsten zouden bij het compleet zijn van de vragenlijsten alleen positiever uitvallen.

Een beperking van deze studie is dat een aantal verschillende typen totaleheupprothesen zijn geïncludeerd. Hoewel ze allemaal volledig gecementeerd zijn, waren er verschillende merken en typen aanwezig. We hebben niet gekeken naar verschil in activiteitsniveau of (over)gewicht. Deze factoren kunnen echter wel een rol spelen bij de mate van overleving en vereisen verder aanvullend onderzoek.[21,22]

Conclusie

Uiteraard moet het besluit om een totaleheupprothese te plaatsen bij jonge patiënten zeer zorgvuldig overwogen worden door de patiënt en arts, maar de resultaten van gecementeerde totaleheupprothesen bij patiënten die ten tijde van de operatie jonger

dan 40 jaar zijn, eventueel in combinatie met reconstructie van acetabulaire defecten met geïmpacteerde botsnippers laten een goede langetermijnoverleving zien van de prothesen.

Referenties

1. Chmell MJ, Scott RD, Thomas WH, Sledge CB. Total hip arthroplasty with cement for juvenile rheumatoid arthritis: results at a minimum of ten years in patients less than thirty years old. *J Bone Joint Surg Am* 1997;79:44-52.
2. Schmalzried TP, Huk OL. Patient factors and wear in total hip arthroplasty. *Clin Orthop Relat Res* 2004;418:94-7.
3. Kobayashi S, Eftekhar NS, Terayama K, Joshi RP. Comparative study of total hip arthroplasty between younger and older patients. *Clin Orthop Relat Res* 1997;339:140-51.
4. Schreurs BW, Busch VJJF, Veth RPH. Keuze van heupprothese voor patiënten jonger dan 50 jaar. *Ned Tijdschr Geneeskd* 2007;151:1918-22.
5. Schreurs BW, Slooff TJJH, Gardeniers JWM, Buma P. Acetabular reconstruction with bone impaction grafting and a cemented cup. *Clin Orthop Relat Res* 2001;393;202-215.
6. Schreurs BW, Busch VJJF, Welten ML, Verdonschot N, Slooff TJJH. Acetabular reconstruction with impaction bone grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86:2385-92.
7. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG, Steinberg ME, Stulberg SD, Wedge JH. Classification and management of acetabular abnormalities in Total hip arthroplasty. *Clin Orthop Relat Res* 1989;243:126-37.
8. Busch VJJF, Gardeniers JWM, Slooff TJJH, Veth RPH, Schreurs BW. Goede langetermijnresultaten van een gecementeerde totaleheupprothese in combinatie met een acetabulumreconstructie met geïmpacteerde botsnippers bij patiënten jonger dan 50 jaar. *Ned Tijdschr Geneeskd* 2007; 151:1935-40.
9. Schreurs BW, Waal Malefijt MC de, Heereveld HA van, Slooff TJJH, Gardeniers JWM, Veth RPH. Totaleheupprothesen bij reumatoïde artritis na acetabulumreconstructie met geïmpacteerde botsnippers en een gecementeerde polyethyleenkom: weinig aseptische komloslatingen. *Ned Tijdschr Geneeskd* 2001;145:1008-12.
10. National Institute for Clinical Excellence (NICE). Guidance on the selection of prostheses for primary hip replacement. London: NICE;2003.
11. Sochart DH, Porter ML. Long-term results of total hip replacement in young patients who had ankylosing spondylitis. *J Bone Joint Surg Am* 1997;79:1181-9.
12. Sochart DH, Porter ML. The long-term results of Charnley Low-friction Arthroplasty in young patients who have congenital dislocation, degenerative osteoarthritis, or rheumatoid arthritis. *J Bone Joint Surg Am* 1997;79:1599-1617.
13. Sochart DH, Porter ML. Long-term results of Charnley low-friction arthroplasty in patients aged less than 30 years. *J Arthroplasty* 1998;13:123-31.
14. Torchia ME, Klassen RA, Bianco AJ. Total hip arthroplasty with cement in patients less than twenty years old. *J Bone Joint Surg Am* 1996;78:995-1003.
15. Bizot P, Banallec L, Sedel L, Nizard R. Alumina-on-alumina total hip prostheses in patients 40 years of age or younger. *Clin Orthop Relat Res* 2000;379:68-76.
16. Chiu KY, Ng TP, Tang WM, Poon KC, Ho WY, Yip D. Charnley total hip arthroplasty in Chinese patients less than 40 years old. *J Arthroplasty* 2001;16:92-101.
17. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC. Long-term results of Charnley low-friction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75:616-23.
18. McAuley JP, Szuszczewicz ES, Young A, Engh CA. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-25.
19. Duffy GP, Berry DJ, Rowland C, Cabanela ME. Primary uncemented total hip arthroplasty in patients <40 years old. *J Arthroplasty* 2001;16:140-4.
20. Chiu KY, Tang WM, Ng TP, Poon KC, Ho WY. Cementless total hip arthroplasty in young Chinese patients. *J Arthroplasty* 2001;16:863-70.
21. Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *J Arthroplasty* 1998;13;890-895.
22. Sechrest VF, Kyle RF, Marek DJ, Spates JD, Saleh KJ et al. Activity level in young patients with primary total hip arthroplasty: a 5-year minimum follow-up. *J Arthroplasty* 2007;22;39-47.

Chapter 6

Good results with cemented total hip arthroplasty in patients between 40-50 years of age
168 hips followed for 2-19 years

D.C.J. de Kam
J.W.M. Gardeniers
R.P.H. Veth
B.W. Schreurs

Acta Orthopaedica 2010;81(2):165-70.

Abstract

Background and purpose. Total hip arthroplasties in young patients have lower long-term survival rates relative to older patients. We have evaluated the use of a unique treatment protocol in patients aged between 40 and 50 years. In all cases we used a cemented THA, in case of acetabular deficiencies we used also impacted bone grafts together with a cemented cup.

Methods. In 140 consecutive patients who were between 40 and 50 years at index surgery 168 cemented total hip prostheses were evaluated after a mean follow-up of 10 (2-19) years. Acetabular deficiencies were reconstructed with wire meshes and impacted bone grafts and a cemented cup (70 hips). During follow-up 18 patients (27 hips) died, in this group 3 hips (3 patients) were revised. No patient was lost to follow up. In all surviving patients clinical assessment was performed with hip scores questions and all radiographs were evaluated.

Results. All clinical questionnaires showed an improved clinical hip score. 29 hips (17%) were revised after a mean of 8 (0.3-18) years. Kaplan-Meier survival analysis showed a survival of 88% (95%CI 82-94%) after 10 years with revision for any reason of either component. Survival with endpoint revision for aseptic loosening of either component was 94% (95%CI 90-99%) after 10 years.

Interpretation. Cemented implants in young patients have satisfying long-term results. Reconstruction of acetabular deficiencies with impacted bone grafts show promising results.

The outcome of total hip arthroplasty who are younger than 50 years is less favorable than in older patients.[1] Therefore, many designs and modifications have been tried during the last 25 years to improve the outcome in younger patients, including cemented hips, uncemented hips, hybrids and resurfacing hip arthroplasty.

We have consequently used cemented total hip implants with a metal on polyethylene bearing also in younger patients. In cases of acetabular bone stock loss, which is common in these patients, we have reconstructed the bone defects using bone impaction grafting and a cemented cup. We have used this method for the last 30 years; which guarantees no selection bias using also other techniques in selected patients. As a referral centre we accept all patients, do not refer patients and we are not performing surgery on patients who are part of this cohort outside our center.

We analyze the outcome in all patients who were between 40 and 50 years at the time of surgery during January 1988 to July 2004.

Patients and methods

Patients

All patients aged between 40 and 50 years who underwent a primary THA between January 1988 and July 2004 at our Department are included in the study. All indications were included, with the exception of oncologic cases. We only used a cemented THA and in case of acetabular deficiencies, these defects were reconstructed with bone impaction grafting together with a cemented cup. 168 consecutive hips in 140 patients (74 female) were operated (Table 1). 28 patients had a bilateral THA. The mean age at index surgery was 46 (40-49) years. 58 patients were class A, 13 B, 49 BB, and 48 C according to the modified Charnley classification.[2]

During follow-up 18 patients (27 hips) died, all due to causes not related to the arthroplasty. All these patients were followed until death and their data are included. Two patients (2 hips) were unable to have a clinical and radiological review, both were interviewed by telephone and stated that the hip was functioning well. The mean follow-up of all patients was 9.7 (2.0-19.3) years. The follow-up of patients available for review (deceased and revised patients excluded) was 10.3 (2.7-19.3) years.

Implants

We used only cemented implants. Femoral stems inserted were: Exeter (n=75) (Stryker Howmedica, Newbury, U.K.), Charnley / Charnley Elite / Charnley Elite+ (n=22, 31, and 23 respectively) (DePuy, Leeds, U.K.) and Müller Straight Stem (n=17) (Sulzer, Wintherthür, Switzerland). The Charnley stems were the only collared stems used. Mean follow-up was 16 years for the Müller implants, 12 years for the Charnley implants, and 6 years for the Exeter implants.

The acetabular components used were: Exeter / Contemporary cups with inner diameter 28mm (n=63) and 22mm (n=1) (Stryker Howmedica, Newbury, U.K.), Charnley / Charnley Elite / Charnley Elite+ / Ogee cups with inner diameter 22.225mm (n=10) or 28mm (n=72) (DePuy, Leeds, U.K.) and Müller cups with inner diameter 28mm (n=3) and 32mm (n=19) (Sulzer, Wintherthür, Switzerland). All cups were made of conventional high molecular weight polyethylene and all femoral heads were made of a cobalt-chrome alloy; no metal backed liners and ceramic femoral heads were used.
72 hips (43%) had an acetabular deficiency. According to the AAOS classification[3] 19 hips had a segmental defect (type I), 41 a cavitair defect (type II), and 12 a combined segmental and cavitair defect (type III).

Surgery

All patients were given prophylactic antibiotics prior surgery. All but 1 operation (anterolateral approach) were performed using a posterolateral approach. No trochanteric osteotomies were performed. In the 72 hips with acetabular deficiencies, the defect was reconstructed in 70 hips with bone impaction grafting and if indicated metal meshes.[4] In 2 hips with segmental rim defects the defect was reconstructed with a

Table 1. Indications for primary total hip arthroplasty.

Indications	No. of hips	Corticosteroids induced avascular necrosis	No. of Hips
Congenital hip dysplasia	39	Kidney transplantation	14
Rheumatoid Arthritis	24	Hodgkin's disease	6
Perthes' disease	5	Aplastic anaemia	3
Avascular necrosis eci	6	Non-Hodgkin lymphoma	2
Epiphysar dysplasia	2	Myelodysplastic syndrome	2
Posttraumatic osteoarthritis	11	Henoch Schonlein disease	1
Bechterew's disease	1	Eczema	1
Posttraumatic avascular necrosis	5	Colitis ulcerosa	1
Synovitis Villonodularis Pigmentosa	1	COPD	1
Epiphysiolysis	6	Pulmonary sarcoïdosis	1
Coxitis	3	Vasculitis	1
Protrusio acetabuli	7		
Osteomyelitis	2	Total	33
Primary osteoarthrosis	17		
TBC coxitis	3		
Achondroplasia	1		
Osteopetrosis	1		
Alcohol induced avascular necrosis	1		
Corticosteroids induced avascular necrosis	33		
Total	168		

solid graft. In 2 cases only allograft was used because the femoral head was not suitable for grafting; in 67 cases autograft was used; in 3 cases both allo- and autograft was used because of an extensive acetabular defect.

Both prosthetic components were inserted with 2nd or 3rd generating cementing techniques with vacuum mixed antibiotic loaded cement, cement pressurizing with a cement gun, pulse lavage, and a distal intramedullary femoral plug. Patients with large acetabular reconstructions were mobilized with partial weight bearing, increased to full weight bearing after 12 weeks. Cases of an extensive acetabular reconstruction had a bed rest period up to maximal 6 weeks. Postoperatively, patients received oral anticoagulants for 3 months or low molecular heparin for 6 weeks. NSAID's were given to prevent heterotopic ossifications.

Clinical evaluation

All patients were periodically followed at our out-patient clinic with an interview, physical examination and radiographs. Clinical outcome was evaluated with several questionnaires: the Harris Hip Score (HHS),[5] the Oxford Hip Questionnaire Score (OHQS, since 1998),[6] and Visual Analogue Scales (VAS, 0-100) assessing pain at rest, pain during physical activities (worst score 100) and satisfaction (best score 100). Clinical questionnaires were obtained by independent researchers at our out-patient clinic.

Radiographical evaluation

All pre- and postoperative anteroposterior and lateral radiographs of every patient were assessed for: position,[7] incorporation of grafts, acetabular defects,[3] position of wire meshes, heterotopic ossifications,[8] polyethylene wear,[9] rounding-off of the calcar, and radiolucent lines. Loosening of the cup was defined as a demarcation in ≥2 zones around the acetabular component of ≥2 mm, progressive demarcation, component migration of ≥3 mm, component tilting of ≥8° and/or cement/prosthesis fracture. We recorded the acetabular radiographic changes according to the zones of DeLee and Charnley.[10] Determination of cup migration was measured in relation to the inter-teardrop line instead of the Kohlerline.[11] Definite loosening of the stem was defined according the criteria of Harris et al..[12] Femoral radiographic changes were recorded by the Gruen zones. All measurements were corrected for radiographic magnification.

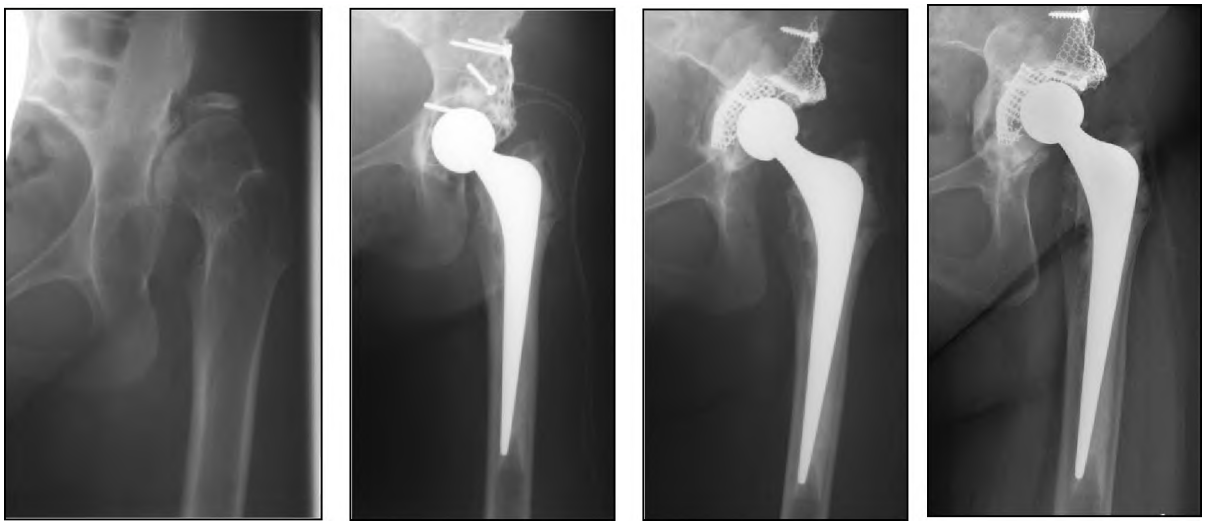


Figure 1A-C: A 43-year-old female with developmental dysplasia of the hips with high dislocation. Preoperative (A), direct postoperative after primary THA with distalization and reconstruction of the cup to its anatomical centre of rotation giving a neurological deficit(B), postoperatively after cup revision 2 years later with cranialization of the cup (C), and 12 years postoperative after cup revision (D).

Statistics

Kaplan-Meier cumulative survival analysis was used to calculate survival rates. Endpoints used for survival analysis were: revision for any reason, revision for any reason excluding infections, revision for aseptic loosening and radiographic loosening. Survival rates were calculated for the whole THA and cup and stem separately. The survival rates at 10 and 12.5 years are reported, because up to 12.5 years more than 25% of the patients were still remaining in the study population. The Student t-test and Chi-square test were also used in statistical analysis. For finding differences in survival the log-rank test was used. A p-value of <0.05 was considered significant.

Results

Clinical results

All clinical postoperative questionnaires scores improved. The median HHS improved from 51 (2-79; n=110) points to 94 (10-100; n=126) points ($p<0.001$). The median OHQs (best score is 12 and the worst score 60) improved from 38 (12-57; n=24) points to 16 (12-45; n=121) points ($p<0.001$). The median postoperative VAS scores for pain at rest, pain during physical activity and satisfaction were 0 (0-80; n=126) points, 0 (0-90; n=126) points, and 100 (0-100; n=124) points respectively.

Revisions

After a mean follow-up of 9.7 (2 -19.3) years, 29 hips (17%) were revised (Table 2). Mean time to revision was 8.1 (0.3-18.4) years. Main reasons for revision were septic loosening (n=5), recurrent dislocations (n=5) and aseptic loosening (n=15). No statistically significant differences were found between the cups with and without impacted bone grafts in time to revision and the number of revisions. Remarkably, all the hips revised for septic loosening and all the cups revised because of recurrent dislocations were THA without an acetabular reconstruction. Of the hips revised because of infection, only 1 patient had had an infection within 2 years (0.9 years). All other revisions were performed because of late infections. 2 stems fractured, in 1 case an Exeter stem and in the other a Charnley Elite stem. In one patient with a high dislocation of the hip because of developmental dysplasia (Figure 1A) an acetabular reconstruction was performed at the original centre of rotation and the cup was distalized (Figure 1B).

As a result of this distalization, tension on the sciatic nerve resulted in a persistent sensory and motor deficit. After 2.4 years the cup was revised to a higher position (Figure 1C) and the neurological deficit partly recovered. The percentages of revisions were equally spread during time for implant types and diagnoses.

Radiographic results

The most recent radiograph was missing in 2 patients. 23 hips were radiographical loose. In 16 cases the cup, in 6 cases the stem and in 1 case both stem and cup were radiographical loose. Of these 23 hips, 18 were revised.

The average wear of the non-revised hips was 0.11 (0.00-1.23) mm/yr and the average wear of the revised hips was 0.26 (0.00-1.04) mm/yr ($p<0.001$). Excessive wear of >0.1 mm/yr was observed in 77 hips (23 revised and 54 non-revised, $p<0.001$). The wear of cups reconstructed with impacted bone grafts and cups implanted without bone grafts were similar. An abnormal position of the cup was not associated with higher wear. Radiographical loose cups showed higher wear rates in contrast to radiographical stable cups (average 0.23 vs. 0.13 mm/yr, $p=0.01$).

All grafts incorporated and none showed osteolytic signs. However, in some cases the used meshes blurred the examination of the incorporation of the grafts. Cups reconstructed with impacted bone grafts showed less radiolucent lines and less acetabular osteolysis. 51 hips had heterotopic ossifications. 25 Brooker class I, 16 class II, and 10 class III.

Complications

In addition to the 5 revisions done for recurrent dislocations, 14 other patients (8%) had 1 or more hip dislocation, all were treated non-operatively. 2 patients had pain and limited hip motion and had heterotopic ossifications excised. 4 patients had temporary nerve palsies (3 cases with developmental dysplasia of the hips and 1 case after septic coxitis at childhood age). A postoperative superficial wound infection occurred in 4 patients and healed with antibiotics. In 1 case a postoperative hematoma was evacuated because of pressure on the sciatic nerve. Cement leakage through DHS screw holes at the greater trochanter was removed because of pain in 1 patient.

Survival analysis

Kaplan-Meier survival analysis with endpoint revision for any reason of any component was 88% at 10 years and 80% at 12.5 years (Table 3). Excluding the infections the survival rates increased to 91% at 10 years and 83% at 12.5 years. Survival with endpoint revision for aseptic loosening of any component was 94% at 10 years and 89% at 12.5 years (Figure 2). There were no statistically significant differences in survival between the different Charnley classifications. With endpoints revision for any reason and revision for aseptic loosening the survival rates were similar in patients with a bilateral or unilateral THA ($p=0.3$ and $p=0.5$), therefore no outcome bias concerning bilateral or unilateral THA is present.[13]

Table 2. Reasons for revision and components revised.

Reason for revision	THA	Cup	Stem	Total	Mean time till revision (range)
Aseptic loosening	9	5	1	15	10.4 (2.5-18.4)
Septic loosening	5	0	0	5	5.0 (0.9-12.9)
Recurrent dislocations	0	4	1	5	4.1 (0.3-11.4)
Fracture	0	0	2	2	8.5 (6.6-10.4)
Traumatic loosening	0	1	0	1	15.0
Neuropathy	0	1	0	1	2.4
Total	14	11	4	29	8.1 (0.3-18.4)

Table 3. Survival rates (95% CI) with all endpoints at 10 and 12.5 years.

Component	Any reason		Any reason excl. infections		Aseptic loosening	
	10 years	12.5 years	10 years	12.5 years	10 years	12.5 years
THA	88 (82-94)	80 (72-88)	91 (85-96)	83 (75-91)	94 (89-99)	89 (83-96)
Stem	92 (87-97)	88 (81-95)	95 (91-99)	91 (84-97)	97 (93-100)	94 (88-99)
Cup	90 (84-95)	84 (77-91)	92 (88-97)	86 (79-93)	94 (89-99)	91 (84-97)

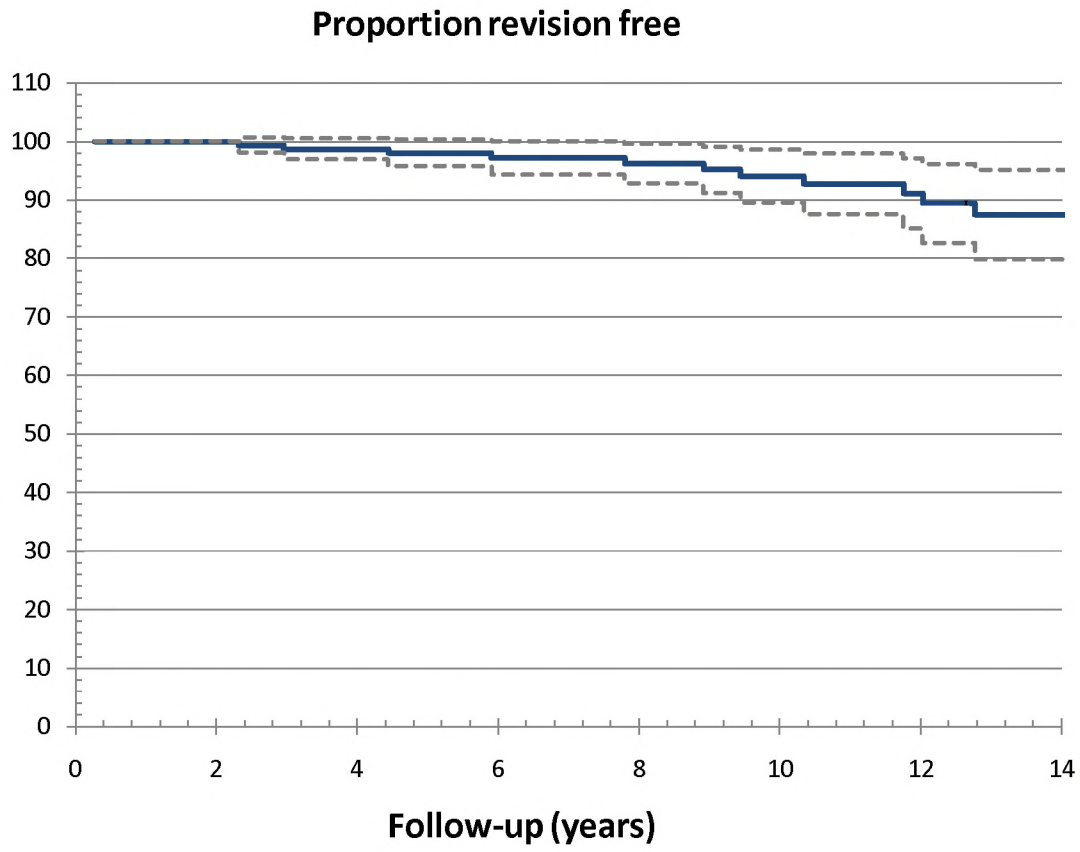


Figure 2. Kaplan-Meier survival curve with endpoint revision for aseptic loosening of any component. (95% confidence intervals in broken lines).

Discussion

We believe our findings are relevant and reliable because we report a large series of consecutive total hip implantations with no patients lost during follow-up.[14] The used approach was the only technique, so no selection bias was created. Our study is not a single surgeon study, the operations were performed by multiple surgeons.

A limitation of our study is the short follow-up in some patients. Another limitation is that we used different kinds of implants over time; however all were cemented with a full polyethylene cup. The Exeter stems had shorter follow-up, thus the long-term follow-up is mostly depending on the results of the Charnley and Müller implants. Nowadays, we only use the Exeter stem, Exeter / contemporary cups routinely in primary, and also Müller (32mm) cups in revision arthroplasties. Because of the wide range of sizes and off-sets of the Exeter stem no custom-made implants are necessary.

Several studies have shown that an acetabular reconstruction with bone impaction grafting creates a unique bone-cement-cup interface.[15,16] This could be an explanation of

the smaller amount of radiolucent lines we found in the cups reconstructed with bone impaction grafting as also reported by De Kam et al.[17]

Notably, the outcome in our patients who had a cemented THA and cups reconstructed with bone impaction grafting are similar to the results of Charnley THA in older patients.[18,19,20,21]

Good results of cemented THA all with the original Charnley prosthesis in patients under the age of 40 with a mean follow-up longer than 10 years varies between 85% and 93%.[22,23,24,25] In another study, the survival of cemented Charnley-Kerboull THA in patients below and above the age of 40 was the same (90% vs. 89% at 20 years).[19]

We have found no reports on uncemented implants in patients under the age of 40, with a mean follow-up longer than 10 years, and with a survival rate of more than 90% at 10 years with endpoint revision for any reason of any component. If the age limit is increased to include patients under 50, only 1 study report a survival rate of >90% after 10 years of custom made uncemented implants in 33 patients.[26] McAuley et al.[27] reported 85% survival at 10 years with endpoint revision for any reason of any component, in patients below 40 years of age after a mean follow-up of 7 years. In a study on uncemented THA in patients <55 years in the Finnish Arthroplasty Register the survival at 10 years of different kinds of uncemented THAs varied between 62% and 86%.[28]

In a meta-analysis of published literature comparing cemented and uncemented THA,[29] no advantage was found for either procedure when failure was defined as revision of any component or revision of one specific component. They did find a superior survival with cemented fixation in studies including patients of all ages as compared to studies that only studied patients 55 years of age or younger.

Higher wear rates and higher revision rates in young patients are partly contributed to higher activity levels.[30,31] We found similar survival rates in the different Charnley categories. However, we did not asses activity levels with proven methods like questionnaires or accelerometers.

Despite the fact that our clinic is a training university hospital and that these institutions are known to have higher revision rates,[32] our results are similar to those obtained with the Charnley cemented THA in younger patients. Our results emphasize the value of cemented THA in this age specific patient population. Reconstruction of acetabular defects with bone impaction grafting seems to be a promising technique.

References

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007;370 (9597):1508-19.
2. Roder C, Staub LP, Eichler P, Widmer M, Dietrich D, Eggli S, et al. Avoiding misclassification bias with the traditional Charnley classification: rationale for a fourth Charnley class BB. *J Orthop Res* 2006;24(9):1803-8.
3. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG, et al. Classification and management of acetabular abnormalities in total hip arthroplasty. *Clin Orthop Relat Res* 1989;243:126-37.
4. Schreurs BW, Slooff TJ, Gardeniers JW, Buma P. Acetabular reconstruction with bone impaction grafting and a cemented cup: 20 years' experience. *Clin Orthop Relat Res* 2001;393:202-15.
5. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 1969;51(4):737-55.
6. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br* 1996;78(2):185-90.
7. Salvati EA, Im VC, Aglietti P, Wilson PD, Jr. Radiology of total hip replacements. *Clin Orthop Relat Res* 1976;121:74-82.
8. Brooker AF, Bowerman JW, Robinson RA, Riley LH, Jr. Ectopic ossification following total hip replacement. Incidence and a method of classification. *J Bone Joint Surg Am* 1973;55(8):1629-32.
9. Dorr LD, Wan Z. Comparative results of a distal modular sleeve, circumferential coating, and stiffness relief using the Anatomic Porous Replacement II. *J Arthroplasty* 1996;11(4):419-28.
10. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976;121:20-32.
11. Goodman SB, Adler SJ, Fyhrie DP, Schurman DJ. The acetabular teardrop and its relevance to acetabular migration. *Clin Orthop Relat Res* 1988;236:199-204.
12. Harris WH, McCarthy JC, Jr., O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg Am* 1982;64(7):1063-7.
13. Bryant D, Havey TC, Roberts R, Guyatt G. How many patients? How many limbs? Analysis of patients or limbs in the orthopaedic literature: a systematic review. *J Bone Joint Surg Am* 2006;88(1):41-5.
14. Murray DW, Britton AR, Bulstrode CJ. Loss to follow-up matters. *J Bone Joint Surg Br* 1997;79(2):254-7.
15. Heekin RD, Engh CA, Vinh T. Morselized allograft in acetabular reconstruction. A postmortem retrieval analysis. *Clin Orthop Relat Res* 1995;319:184-90.
16. Van der Donk S, Buma P, Slooff TJ, Gardeniers JW, Schreurs BW. Incorporation of morselized bone grafts: a study of 24 acetabular biopsy specimens. *Clin Orthop Relat Res* 2002;396:131-41.
17. De Kam DC, Gardeniers JW, Hendriks JC, Veth RP, Schreurs BW. Cemented polyethylene cups in patients younger than 40 years. *Clin Orthop Relat Res* 2009;467:1753-64.
18. Garellick G, Herberts P, Stromberg C, Malchau H. Long-term results of Charnley arthroplasty. A 12-16-year follow-up study. *J Arthroplasty* 1994;9(4):333-40.
19. Kerboull L, Hamadouche M, Courpied JP, Kerboull M. Long-term results of Charnley-Kerboull hip arthroplasty in patients younger than 50 years. *Clin Orthop Relat Res* 2004;418:112-8.
20. Buckwalter AE, Callaghan JJ, Liu SS, Pedersen DR, Goetz DD, Sullivan PM, et al. Results of Charnley total hip arthroplasty with use of improved femoral cementing techniques. A concise follow-up, at a minimum of twenty-five years, of a previous report. *J Bone Joint Surg Am* 2006;88(7):1481-5.
21. Hulleberg G, Aamodt A, Espehaug B, Benum P. A clinical and radiographic 13-year follow-up study of 138 Charnley hip arthroplasties in patients 50-70 years old: comparison of university hospital data and registry data. *Acta Orthop* 2008;79(5):609-17.
22. Chiu KY, Ng TP, Tang WM, Poon KC, Ho WY, Yip D. Charnley total hip arthroplasty in Chinese patients less than 40 years old. *J Arthroplasty* 2001;16(1):92-101.
23. Garcia-Cimbrelo E, Cruz-Pardos A, Cordero J, Sanchez-Sotelo J. Low-friction arthroplasty in patients younger than 40 years old: 20- to 25-year results. *J Arthroplasty* 2000;15(7):825-32.
24. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC, Hardinge K. Long-term results of Charnley low-friction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75(4):616-23.
25. Sochart DH, Porter ML. The long-term results of Charnley low-friction arthroplasty in young patients who have congenital dislocation, degenerative osteoarthrosis, or rheumatoid arthritis. *J Bone Joint Surg Am* 1997;79(11):1599-617.
26. McCullough CJ, Remedios D, Tytherleigh-Strong G, Hua J, Walker PS. The use of hydroxyapatite-coated CAD-CAM femoral components in adolescents and young adults with inflammatory polyarthropathy: ten-year results. *J Bone Joint Surg Br* 2006;88(7):860-4.
27. McAuley JP, Szuszczewicz ES, Young A, Engh CA, Sr. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-25.
28. Eskelinen A, Remes V, Helenius I, Pulkkinen P, Nevalainen J, Paavolainen P. Uncemented total hip arthroplasty for primary osteoarthritis in young patients: a mid-to long-term follow-up study from the Finnish Arthroplasty Register. *Acta Orthop* 2006;77(1):57-70.
29. Morshed S, Bozic KJ, Ries MD, Malchau H, Colford JM, Jr. Comparison of cemented and uncemented fixation in total hip replacement: a meta-analysis. *Acta Orthop* 2007;78(3):315-26.
30. Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *J Arthroplasty* 1998;13(8):890-5.
31. Schmalzried TP, Huk OL. Patient factors and wear in total hip arthroplasty. *Clin Orthop Relat Res* 2004;418:94-7.

32. Espehaug B, Havelin LI, Engesaeter LB, Vollset SE. The effect of hospital-type and operating volume on the survival of hip replacements. A review of 39,505 primary total hip replacements reported to the Norwegian Arthroplasty Register, 1988-1996. *Acta Orthop* 1999;70(1):12-8.

Chapter 7

Thirty years experience with bone impaction grafting of acetabular deficiencies in combination with a total hip arthroplasty in young patients under fifty years

D.C.J. de Kam
V.J.J.F. Busch
J.W.M. Gardeniers
T.J.J.F. Slooff
R.P.H. Veth
B.W. Schreurs

Submitted.

Abstract

Background. The long-term survival of total hip arthroplasties in younger patients is often disappointing, which can be partly explained by the higher activity levels. However, often these patients have already at the implantation of the primary total hip acetabular deficiencies, which hamper proper implantation of the cup essential for satisfying prosthesis survival. For thirty years, we have used a biological acetabular-reconstruction technique with bone-impaction grafting in all patients under 50 years with an acetabular deficiency at surgery, always in combination with a cemented total hip implant.

Methods. We evaluated all 177 primary cemented hips implanted in 150 consecutive patients who all were younger than 50 years at surgery with an acetabular reconstruction by bone-impaction grafting surgically treated between 1978 and 2004. Mean follow-up was 10.3 years (range, 2.0–28.3 years) with no patient lost to follow-up. Mean index surgery age was 38.1 years (range, 16–49 years). Clinical, radiological, and statistical analysis of all patients was performed.

Results. Twenty-eight of 177 hips were revised at a mean of 10.5 years (range, 5 days to 23.2 years). Reasons for revision were: aseptic loosening (n=17), septic loosening (n=3), recurrent dislocations (n=3), traumatic loosening (n=2), neuropathy (n=1), wear (n=1), and fracture (n=1). Ten-year and 15-year survival of the total hip with endpoint revision of any component for any reason was 91% and 78%, respectively. Ten-year survival with endpoint aseptic loosening was 96% for the cup and 97% for the stem.

Conclusion. Performing a total hip implant in combination with bone impaction grafting in younger patients with acetabular bone stock loss seems to be an attractive approach as the long-term results are acceptable and fulfill the NICE-criteria, showing a ten -year survival of more than 90% with endpoint revisions for any reason.

Based on the excellent results of THA in older patients,[1,2] nowadays THA are used more frequently in younger patients (less than 50 years of age) with pain and limited hip motion. However, despite many efforts, the long-term results of THA in younger patients often are disappointing. In most of the times this lack of success is attributed to the increased demands with higher levels of activities in these younger patients.[3-5] Another explanation however, is the surgical difficulty sometimes experienced in these younger patients. Younger patients often have secondary osteoarthritis because of other underlying diagnoses like developmental dysplasia of the hips, inflammatory arthritis, or avascular necrosis. This secondary osteoarthritis is frequently accompanied by loss of acetabular bone and sometimes even pelvic discontinuities or the absence of supportive rims or walls. One of the major challenges of implanting a total THA in younger patients is therefore the management of these acetabular deficiencies.

Since 1979 we have the philosophy that these acetabular deficiencies in younger patients should be reconstructed at insertion of the primary hip implant using a biological reconstruction technique.[6] From that time on, all cases with bone stock loss have been reconstructed by impacting trabecular autograft bone chips and, if needed, allograft bone chips into the defect. This technique facilitates also good supporting bone bed that can fully contain the cup. Reconstruction with bone impaction grafting restores acetabular bone stock loss and facilitates the reconstruction of the original centre of rotation.[7,8] Another possible advantage of this biological approach is the anticipation of a future revision. Due to the younger age of patients and the limited lifespan of a THA, a revision of a THA in a young patient is inevitable. With restoration of the acetabular bone stock, a probably better basis for future revision is created.

In this study, we present the results of all primary THA with acetabular reconstructions with bone impaction grafting in patients under the age of 50 years since the development of this operative technique 30 years ago in our hospital implanted between 1979 and 2004, with a minimum follow-up of two years. In all cases we combined this biological reconstruction technique with a cemented total hip arthroplasty with a metal on polyethylene bearing. We describe the survival rates, revisions, radiographic analysis, and clinical analysis of all younger patients who ever received operations with this technique at our centre.

Materials and Patients

The study was performed after approval by our institutional review board. Retrospectively, we reviewed prospectively collected data from all consecutive patients who had a primary THA with an acetabular reconstruction with impacted morselized bone

Table 1. Primary indications for total hip arthroplasties.

Diagnosis	Number
Developmental dysplasia of the hip	52
Rheumatoid arthritis	31
Avascular necrosis	21
Posttraumatic osteoarthrosis	14
Protrusio acetabuli	12
Perthes' disease	8
Epiphysar dysplasia	5
Osteomyelitis	5
Epiphysiolysis	4
Primary osteoarthrosis	4
Miscellaneous	21
Total	177

grafts because of an acetabular defect at our department between 1978 and 2004, and who were younger than 50 years of age at the time of index surgery. We included 177 hips in 150 patients. All indications were included and no patients were excluded. No patient was lost to follow-up. All total hip implants had a cemented femoral stem and a cemented acetabular polyethylene cup. Of the 150 patients, 54 (36%) were male and 96 (64%) female. Twenty-seven patients had a bilateral reconstruction with bone impaction grafting. Eighty-three hips were placed on the left side and 94 on the right side. Mean age at index surgery was 38.1 years (range, 16–49 years). According to the American Academy of Orthopaedic Surgeons (AAOS) classification for acetabular defects,[9] 34 (19%) hips had a segmental defect (type I, rim or wall missing), 97 (55%) a cavitair defect (type II, volumetric defect with intact walls and rims), 45 (25%) a combined segmental and cavitair defect (type III), and 1 (0.6%) hip had a bony ankylosis (type V). Primary diagnoses were mainly developmental dysplasia of the hips (29%), rheumatoid arthritis (18%), and avascular necrosis of the femoral head (12%) (Table 1).

Surgical technique of bone impaction grafting

After resection of the femoral head, the acetabulum was prepared and all cartilage and cysts were removed. If needed, segmental defects of the acetabular rim and/or medial wall are first reconstructed with flexible wire meshes, which are trimmed and adapted with special scissors and clamps to contain the defect entirely, and fixed with several self-tapping screws (Stryker-Howmedica, Newburry, United Kingdom)(Figure 1A). After containment with the wire meshes, only a cavitary defect remains. Sclerotic areas are perforated with multiple small drill holes to enhance better vascularisation of the graft. The socket is rinsed with pulse lavage and trabecular bone chips of 0.7–1.0 mm are placed and tightly impacted with specially designed impactors (Figure 1B–C). The impactors increase in size and the size of the last impactor used corresponds to the size

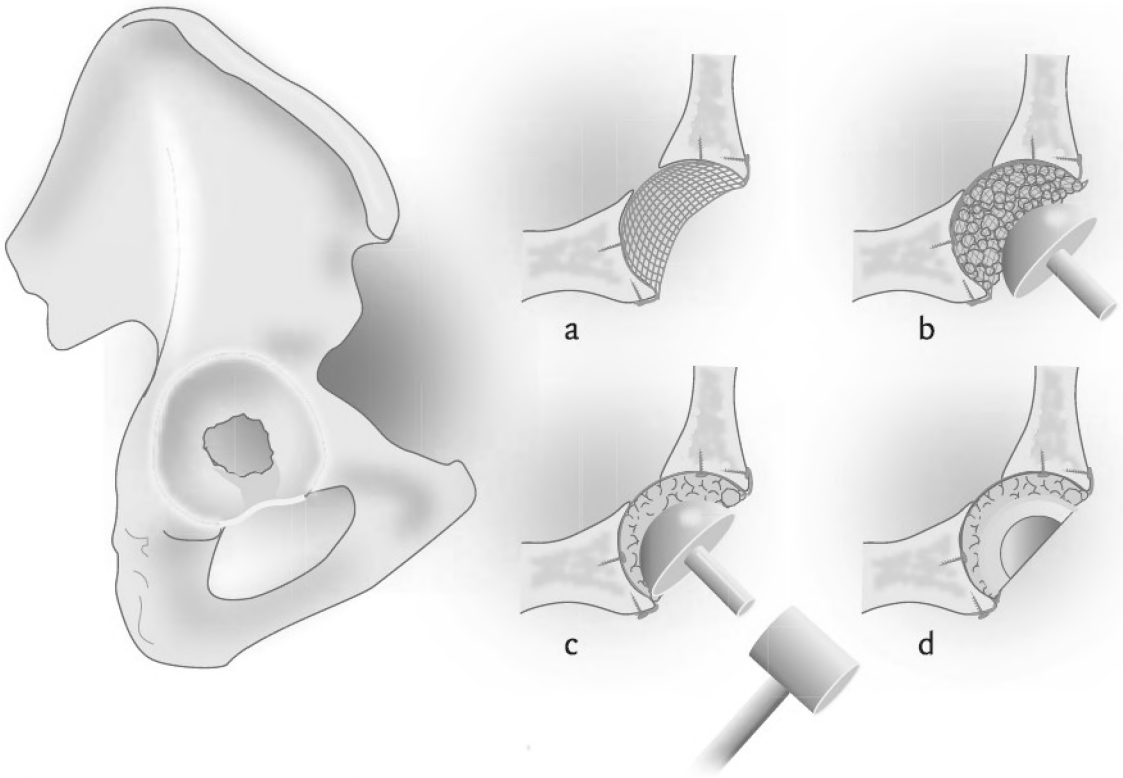


Figure 1. The reconstruction of acetabular defects with bone impaction grafting
Reconstruction of the defects with wire meshes (a), placement of the morselized bone grafts (b), impaction of the bone grafts (c), and the final result with a cemented polyethylene cup (d).[29]

of the polyethylene cup with its cement layer. Multiple layers of graft are impacted until the defect is completely filled. The bone chips are made of autograft from the resected femoral head and, if needed, from fresh frozen human femoral head allografts obtained from a bone bank. The femoral heads are morselized with a special bone mill or by hand with a rongeur. We tried to reconstruct the anatomical position of the centre of rotation with the transverse ligament as reference. Vacuum-mixed cement loaded with antibiotics was used and the cement was pressurized into the trabecular bone and graft. Finally a full polyethylene cup is placed and held in position with a pusher until the cement is polymerized (Figure 1D). Before 1989, we used Palacos bone cement (Merck, Darmstadt, Germany); from 1989 forward, we used Surgical Simplex (Stryker-Howmedica, Newburry, UK). The bone impaction grafting technique has been described in detail in the literature.[10,11]

The femoral component was also inserted using pulse lavage, a distal intramedullary femoral plug, vacuum-mixed cement, and pressurizing the cement with a cement gun and seal.

During this long time period, we used several kinds of implants. All implants were fully cemented and the cups used were made of conventional polyethylene. Only cobalt-chrome and no ceramic femoral heads were used. For the acetabular reconstruction we used 62 (35%) Exeter/Contemporary cups (Stryker Howmedica, Newbury, UK), 69 (39%) Charnley/Elite cups (DePuy, Leeds, UK), and 46 (26%) Müller/Allopro cups (Sulzer, Winterthur, Switzerland). As a femoral component, we used an Exeter stem in 90 (51%) cases (Stryker Howmedica, Newbury, UK), a Charnley/Elite stem in 49 (28%) cases (DePuy, Leeds, UK), and a Müller stem in 38 (21%) cases (Sulzer, Winterthur, Switzerland). Our standard head size was 28mm, in some small acetabuli we used a 22.225 mm heads. All Müller/Allopro cups had an internal diameter of 32 mm.

Postoperative treatment

Patients received antibiotics for 24 hours to prevent infections. Postoperatively, all patients received thrombosis prophylaxis with low-molecular-weight heparin for 6 weeks, or before 1999 with oral anticoagulants for 3 months according to our postoperative protocol. To prevent heterotopic ossifications, we prescribed nonsteroidal antiinflammatory drugs (NSAIDs) for 7 days. When NSAIDs were contraindicated, one dose (7 Gy) of radiotherapy was given postoperatively.

Patients were mobilized under the supervision of a physiotherapist in an individual mobilization protocol. Patients with simple minor cavitair defects were mobilized after 2 days. In case of extended reconstructions, 10% partial weight bearing was allowed for 6 weeks and 50% for another 6 weeks before full weight bearing was permitted. Patients with massive reconstructions had a period of bed rest of up to 6 weeks to achieve full graft incorporation before weight bearing mobilization. Also in the early years of this technique all patients had a 6 weeks bed rest period.

Clinical and radiographical analysis

Routine follow-up visits were scheduled after 6 weeks, 3, 6, and 12 months; and yearly or biannually thereafter. At our out-patient clinic, independent student researchers performed clinical analyses using the Harris hip score.[12] Clinical scores of all patients at their last review excluding the revision patients were given. Clinical failure was defined as the removal or replacement of one or more components of the THA for any reason.

Anteroposterior and lateral radiographs of the THA were obtained and analyzed for the radiographical analysis. All radiographs were evaluated on cup position, meshes, graft incorporation, migration of either component, polyethylene wear according to Dorr et al.,[13] and radiological loosening. Radiological loosening/failure was defined as demarcation in two or three zones around the acetabular component of 2 mm or greater, progressive demarcation, component migration of 3 mm or greater, component tilting of 5° or greater, and/or cement or prosthesis fracture. Radiological failure of the stem was defined according to the definitions of Harris et al..[14]

Statistical analysis
We used Kaplan-Meier curves to calculate the cumulative survival (time to revision). The endpoints were (1) revision for any reason; (2) revision for any reason excluding infections; and (3) revision for aseptic loosening. With an average follow-up of 10.3 years, more than 20% of all patients had a follow-up longer than 15 years. This means our results are representative for the 15-year long-term survival. To test any significant differences, the student t-test or the Chi-square test was used after checking for normal distribution. All calculations were performed with SPSS 16.0.

Source of funding
Although none of the authors has or will receive benefits for personal or professional use from a commercial party directly or indirectly related to the subject of this article, benefits have been or will be received from Stryker-Howmedica (Newbury, United Kingdom), but will be directed solely to a research fund, foundation, educational institution, or other non-profit organisation with which one or more of the authors (BWS, JWMG) are associated.

Results
All 177 hips in 150 patients were included for evaluation. No patient was lost during follow up. In 2 patients, a recent radiograph was missing for the radiological evaluation, and their THA function was based on a telephone interview. Mean follow-up was 10.3 years (range, 2.0–28.3 years). During follow-up, 13 patients died (accounting for 15 hips) from causes unrelated to the surgery. All data until death were used in the analyses.

Clinical outcome scores improved significantly after surgery. The median HHS improved from 47.5 (range, 2–81; n=80), to 91 (range, 10–100; n=152) postoperatively ($p<0.001$).

Twenty-eight of 177 hips (16%) were revised after a mean of 10.2 (range, 0.1–22.5) years (Table 2). Reasons for revision included aseptic loosening (n=17), septic loosening (n=3), recurrent dislocations (n=3), traumatic loosening (n=2), neuropathy (n=1), wear (n=1), and fracture (n=1). In ten cases, both the cup and stem were revised; in three cases only the stem, in fourteen cases only the cup, and in one case only the femoral head (Table 2). Average time to revision of the cups because of aseptic loosening was 12 (range, 2.6–21.2) years. Only one cup was revised solely because of wear after 23.2 years. Three THA (1.7%) were revised because of culture-proven infection after 3.4, 6.1, and 14.5 years, respectively (Table 2). These infections can be defined as haematogenic infection of a well-functioning prosthesis.

Radiological evaluation of all radiographs showed that most hips were radiographically stable (Figure 2 and 3), but nine cups were radiographically loose. All radiographically loose cups ere revised. Seven stems were radiographical loose of which 6 were revised. One stem was fractured after 10 years. The average wear of the non-revised cups was 0.08 mm/year and the wear of the revised cups was 0.17 mm/year (significant difference, independent t-test: $p=0.001$).

Survival analysis of all 177 hips with endpoint revision for any reason of either component showed a survival of 91% and 78% after 10 and 15 years, respectively (Table 3, Figure 4). Aseptic survival of the THA was 95% and 85% after 10 and 15 years, respectively (Figure 5). Survival with endpoint aseptic loosening of the reconstructed cups was 96% and 86% after 10 and 15 years, respectively, in this study (Table 3, Figure 6). Survival with endpoint aseptic loosening of the cemented stems in this study was 97% and 90% after 10 and 15 years, respectively. There was no difference in survival with respect to sex (log-rank, $p=0.087$), AAOS type (log-rank, $p=0.995$), age less than or greater than 40 years (log-rank, $p=0.524$), or type of cup (log-rank,

p=0.420). There was a significant difference in survival regarding the different types of stem used; the Müller stems had better survival (log-rank, p=0.045).

Table 2. Individual patient data of all hip revisions.

Reason for revision	Part(s) revised	Indication	Sex	Side	Age at index surgery (years)	Time to revision (years)
Aseptic loosening	Cup	Rheumatoid arthritis	M	L	23	13.8
Aseptic loosening	Cup	Bechterew's disease	M	R	28	21.2
Aseptic loosening	Cup	Developmental dysplasia of the hips	F	L	49	20.5
Aseptic loosening	Cup	Coxitis	F	L	33	9.7
Aseptic loosening	Cup	Rheumatoid arthritis	F	R	24	4.1
Aseptic loosening	Cup	Rheumatoid arthritis	F	L	23	19.9
Aseptic loosening	Cup	Posttraumatic	M	R	35	16.7
Aseptic loosening	Cup	Posttraumatic	M	R	41	12.2
Aseptic loosening	Cup	Developmental dysplasia of the hips	F	R	45	3.1
Aseptic loosening	Stem	Posttraumatic	M	L	37	2.6
Aseptic loosening	Stem	Posttraumatic avascular necrosis	M	R	47	10.6
Aseptic loosening	THA	Posttraumatic	F	L	47	15.3
Aseptic loosening	THA	Perthes' disease	M	R	41	9.1
Aseptic loosening	THA	Rheumatoid arthritis	F	R	46	9.8
Aseptic loosening	THA	Corticosteroid induced avascular necrosis	M	R	47	12.3
Aseptic loosening	THA	Developmental dysplasia of the hips	F	R	46	13.0
Aseptic loosening	THA	Developmental dysplasia of the hips	F	R	35	16.1
Recurrent dislocations	Cup	Developmental dysplasia of the hips	F	R	43	0.3
Recurrent dislocations	Cup	Corticosteroid induced avascular necrosis	M	L	37	3.5
Recurrent dislocations	Head	Perthes' disease	M	L	34	0.0
Septic loosening	THA	Posttraumatic	M	R	38	14.5
Septic loosening	THA	Corticosteroid induced avascular necrosis	M	R	32	3.4
Septic loosening	THA	Avascular necrosis with unknown cause	F	R	25	6.1
Traumatic	Cup	Protrusio acetabuli	F	L	43	14.9
Traumatic	THA	Rheumatoid arthritis	F	R	23	6.4
Fracture	Stem	Epiphysiolysis	F	L	43	10.4
Neuropathy	Cup	Developmental dysplasia of the hips	F	L	43	2.4
Wear	Cup	Posttraumatic avascular necrosis	F	L	37	23.2

Table 3. Cumulative survival with endpoints revision for any reason, revision for any reason excluding infections, and aseptic loosening.

Component	Any reason		Any reason excluding infections		Aseptic loosening	
	10 years	15 years	10 years	15 years	10 years	15 years
THA, Mean (95%CI)	90.8 (85.8–95.8)	77.9 (68.1–87.7)	92.1 (87.3–96.9)	79.0 (69.2–88.8)	95.1 (91.1–99.1)	84.8 (76.0–93.6)
Stem, Mean (95%CI)	95.2 (91.2–99.2)	87.2 (79.2–95.2)	96.6 (93.2–100)	88.5 (80.7–96.3)	97.4 (94.4–100)	90.3 (82.7–97.9)
Cup, Mean (95%CI)	91.9 (87.1–96.7)	80.7 (71.1–90.3)	93.2 (88.6–97.8)	81.9 (72.3–91.5)	95.7 (92.9–98.5)	86.3 (77.5–95.1)

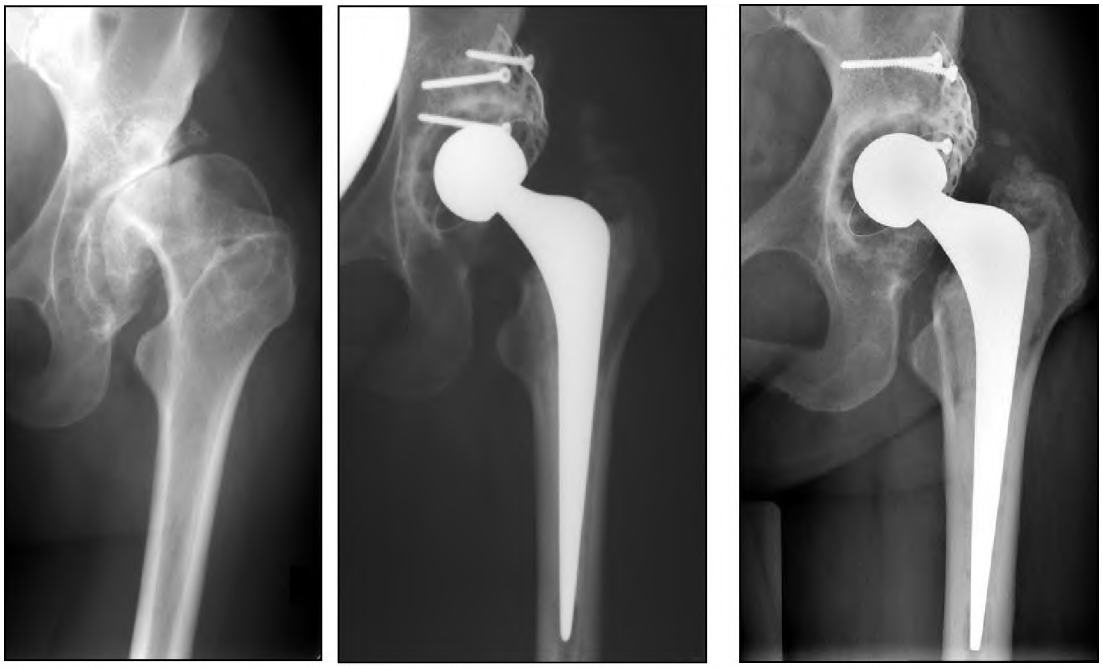


Figure 2. AP radiographs of a 35 years-old female with developmental dysplasia of the hip. Preoperative AP radiographs of the left hip to be reconstructed (A), immediately postoperative (B), and 14 years postoperative (C) showing a radiological stable view.

Discussion

To our best knowledge, this is the first study focused on the outcome of total hip arthroplasty in a specific and highly demanding group of younger patients; those with pre-existing acetabular bone stock loss. It is remarkable that, using a biological approach with acetabular bone impaction grafting and a cemented total hip arthroplasty in this very young group of patients, the survival with endpoint revision for any reason was more than 90% at 10 years, thereby fulfilling the standards defined by the National Institute of Clinical Excellence (NICE) that states that a good prosthesis should have a survival of more than 90% after 10 years with endpoint revision for any reason.[15]

The study is based on 30-years experience using a biological method, which can reconstitute bone stock. During these 30 years, there has been only one modification of the technique. Initially, a metal mesh was placed on top of the impacted bone grafts to prevent extensive contact between the bone cement and bone grafts because there was some concern whether extensive contact between the graft and the cement would harm graft incorporation.[16] However, we have abandoned this mesh since 15 years as we realized that this mesh was useless. In our study group we found no statistical difference between the reconstructions with or without mesh on the top of the impacted bone graft. Techniques with a proven long-term survival are needed, especially in younger patients.[15,17] Our paper is a single institution report presenting the outcome of all cases with bone impaction grafting performed by several different surgeons in patients less

than 50 years of age over the 30-year period that we have used this technique. It is still the only technique we use in these cases. The follow-up is complete, and all cases, including the initial patients operated on before we gained extensive experience in the technique, are included. Since no case was lost, the reliability of our data according to Murray et al. is high.[18] Because we are a referral centre, we accept all cases and do not refer cases to other institutions. We have used bone impaction grafting in about 40% of all patients who were less than 50 years of age. If there is no bone deficiency, we perform a standard, cemented, total hip implant.

A limitation of the study is that, during this very long follow-up, several types of cemented cups and stems were used. However, in our current practice we still use two of these cups (Exeter contemporary cup and Muller cup) and the Exeter stem. Because all primary diagnoses are included, the primary diagnoses in our population are very heterogeneous; however, all had acetabular bone stock deficiencies. Since the bone impaction grafting technique is the only technique we use in the reconstruction of acetabular deficiencies, it is impossible to make comparisons between different reconstruction techniques in our department. One may argue that we also included smaller cavitary defects reconstructed by bone impaction grafting, which could also be addressed by more cement or non-cemented cups. However, we compare our data to reports based on the outcome of total hips in patients less than 50 years of age that are not focused on patients with bone deficiencies. A drawback of the method is that patients have to use crutches for 3 months, in extensive cases sometimes we use a 6 weeks bed rest period.

Although acetabular bone stock deficiencies are frequent in younger patients with secondary osteoarthritis, it is remarkable that no other studies are focused on the outcome of reconstructions in patients less than 50 years of age with these bone stock defects. Currently, noncemented total hip implants are very popular in younger patients, implants.[15,17] Remarkably, screening the literature on 01-01-2009 there is only one

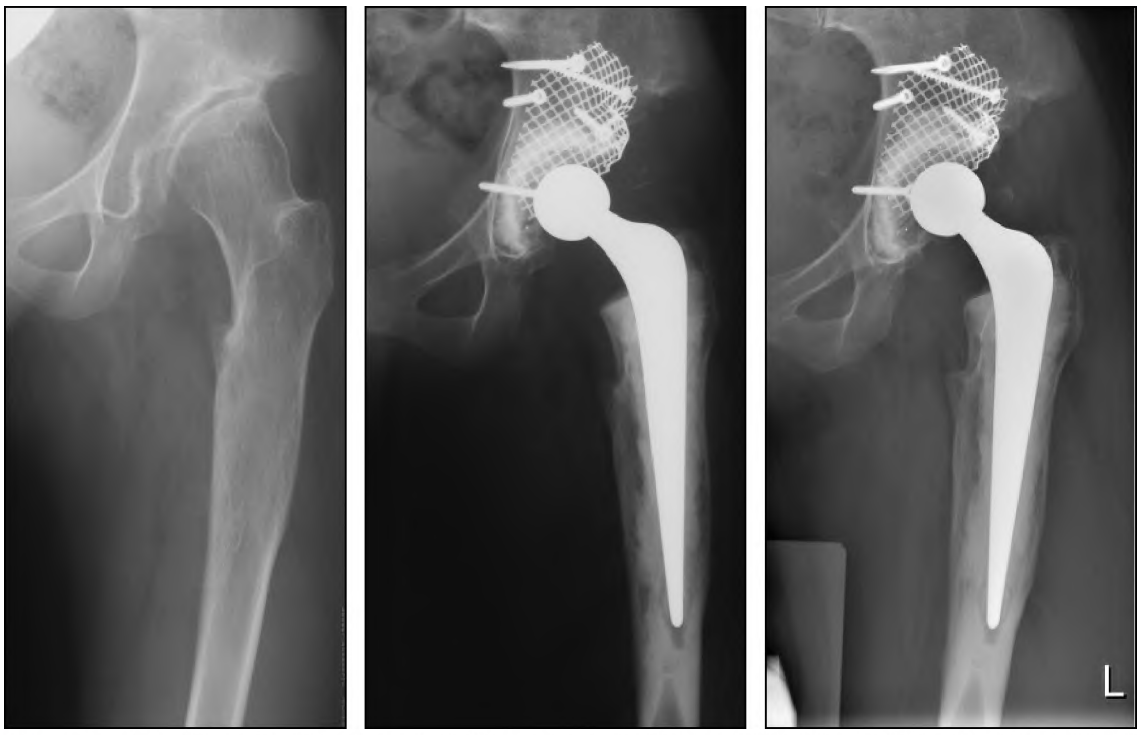


Figure 3. AP radiographs of a 19 years-old female with developmental dysplasia of the hip. Preoperative AP radiographs of the left hip to be reconstructed (A), immediately postoperative (B), and 7 years postoperative (C) showing a radiographically stable view.

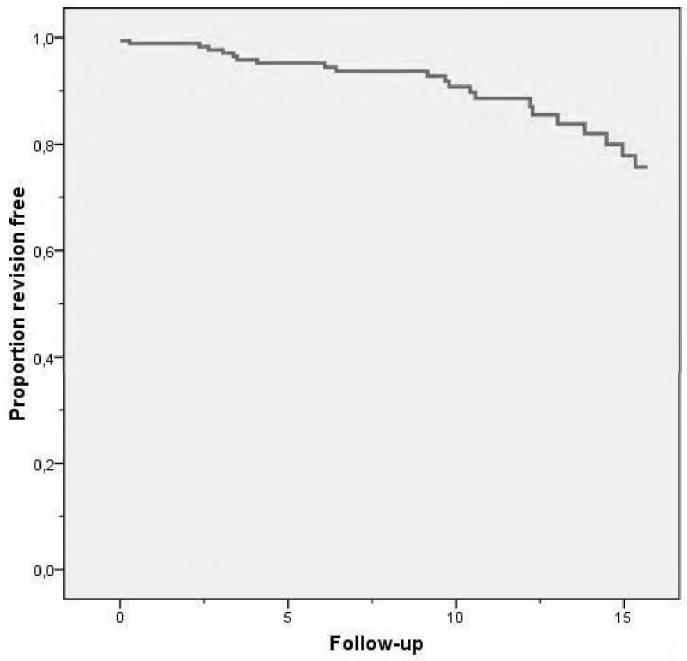


Figure 4. Kaplan-Meier survival analysis with endpoint revision of either component for any reason.

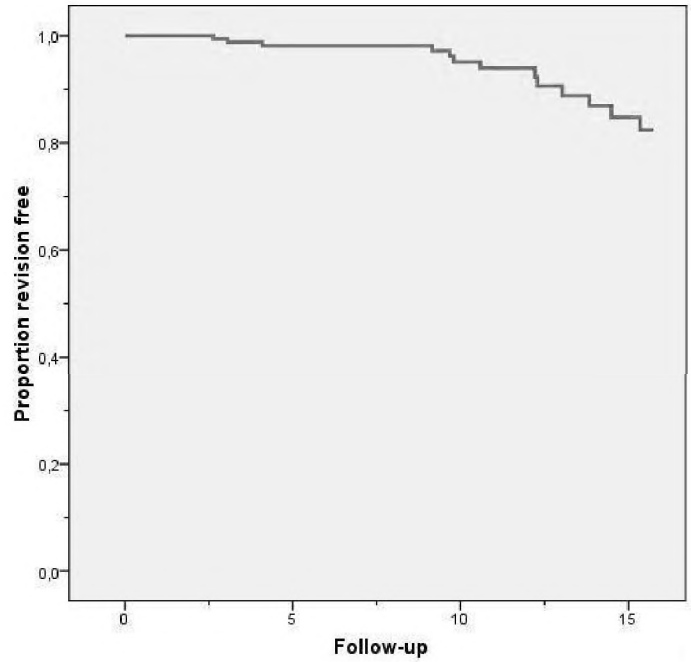


Figure 5. Kaplan-Meier survival analysis with endpoint revision of either component for aseptic loosening.

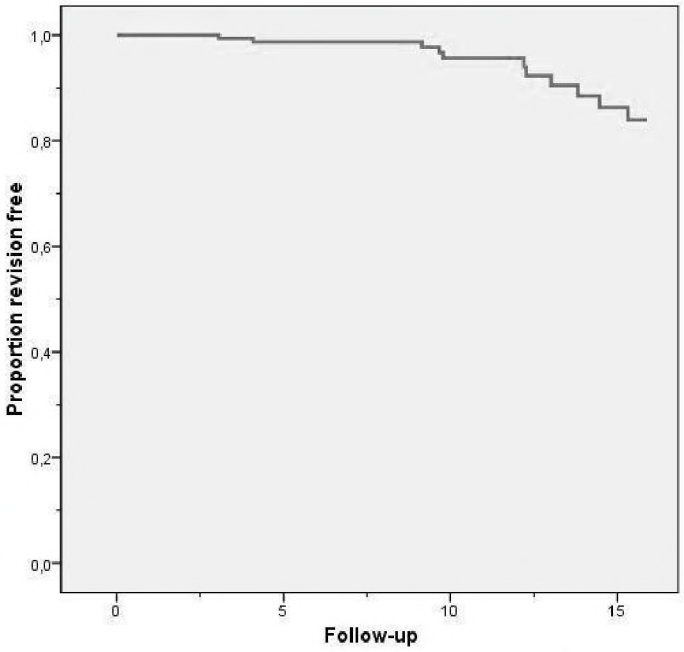


Figure 6. Kaplan-Meier survival analysis with endpoint revision of the cup for aseptic loosening.

report of uncemented total hip arthroplasty, and no reports of metal-on-metal resurfacing total hip arthroplasty techniques, that have a reported minimal survival rate of 90% at 10 years in patients less than 50 years of age.[19] There are reports based on cemented implants that do fulfil these criteria; however, these reports do not focus on younger patients with acetabular bone stock loss, although a certain subset of these patients will have pre-existing bone stock loss.[20-22] There have been long-term reports on the application of bone impaction grafting in primary total hip prostheses, but most reports do not focus on the outcome of this technique in younger patients.[23,24] We have reported the outcome of the bone impaction grafting technique in young patients previously; however, the earlier study was based on a limited number of 42 acetabular reconstructions in both primary (n=23) and revision hips (n=19), and only the outcome of the acetabular component was reported.[25] At 10 years, the survival rates for the cup were 92% (95% CI 83.5–100%) and 97% (95% CI 92.1–100%) with endpoint revision for any reason and revision for aseptic loosening, respectively. This is comparable to the outcome of the cup in the current study (92% and 96%) based on many more cases. An attractive aspect of the technique is that the bone stock loss is reconstructed by bone transplantation. There is evidence, both from animal studies and human biopsies, that these bone grafts do indeed incorporate into normal human bone.[7,8] By using this approach, the outcome of future revisions is probably less demanding because more bone may be available.

Achieving good survival rates for total hip arthroplasties in younger patients is difficult. Acetabular deficiencies make this challenge even harder. Younger patients are dependent on proven long-term survival of prostheses and the outcome of both the femoral and acetabular component is important. The latter is often a flaw in many reports on total hip arthroplasty, because they are often focused on one component. This study shows that the use of bone impaction grafting is very attractive in total hip arthroplasty in younger patients with acetabular deficiencies. Bone impaction grafting restores the loss of bone stock and creates a natural, anatomic, biomechanical situation and produces satisfactory survival rates, which fulfill the NICE-criteria 10 years after implantation.

References

1. Charnley J. Arthroplasty of the hip. A new operation. *Lancet* 1961;7187:1129-32.
2. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007;370:1508-19.
3. Kobayashi S, Eftekhar NS, Terayama K, Joshi RP. Comparative study of total hip arthroplasty between younger and older patients. *Clin Orthop Relat Res* 1997;339:140-51.
4. Schmalzried TP, Huk OL. Patient factors and wear in total hip arthroplasty. *Clin Orthop Relat Res* 2004;418:94-97.
5. Sechriest VF, 2nd, Kyle RF, Marek DJ, Spates JD, Saleh KJ, Kuskowski M. Activity level in young patients with primary total hip arthroplasty: a 5-year minimum follow-up. *J Arthroplasty* 2007;22:39-47.
6. Harris WH. The problem is osteolysis. *Clin Orthop Relat Res* 1995;311:46-53.
7. Slooff TJ, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop* 1984;55:593-96.
8. Heekin RD, Engh CA, Vinh T. Morselized allograft in acetabular reconstruction. A postmortem retrieval analysis. *Clin Orthop Relat Res* 1995;319:184-90.
9. van der Donk S, Buma P, Slooff TJ, Gardeniers JW, Schreurs BW. Incorporation of morselized bone grafts: a study of 24 acetabular biopsy specimens. *Clin Orthop Relat Res* 2002;396:131-41.
10. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG, et al. Classification and management of acetabular abnormalities in total hip arthroplasty. *Clin Orthop Relat Res* 1989;243:126-37.
11. Schreurs BW, Gardeniers JW, Slooff TJ. Acetabular reconstruction with bone impaction grafting: 20 years of experience. *Instr Course Lect* 2001;50:221-28.
12. Schreurs BW, Slooff TJ, Gardeniers JW, Buma P. Acetabular reconstruction with bone impaction grafting and a cemented cup: 20 years' experience. *Clin Orthop Relat Res* 2001;393:202-15.
13. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 1969;51:737-55.
14. Dorr LD, Wan Z. Comparative results of a distal modular sleeve, circumferential coating, and stiffness relief using the Anatomic Porous Replacement II. *J Arthroplasty* 1996;11:419-28.
15. Harris WH, McCarthy JC, Jr., O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg Am* 1982;64:1063-67.
16. Guidance on the Selection of Prostheses for Primary Total Hip Replacement. London: National Institute for Clinical Excellence; 2000.
17. Jones LC, Hungerford DS. Cement disease. *Clin Orthop Relat Res* 1987;225:192-206.
18. McAuley JP, Szuszczewicz ES, Young A, Engh CA, Sr. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-25.
19. Murray DW, Britton AR, Bulstrode CJ. Loss to follow-up matters. *J Bone Joint Surg Br* 1997;79:254-57.
20. McCullough CJ, Remedios D, Tytherleigh-Strong G, Hua J, Walker PS. The use of hydroxyapatite-coated CAD-CAM femoral components in adolescents and young adults with inflammatory polyarthropathy: ten-year results. *J Bone Joint Surg Br* 2006;88:860-64.
21. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC, Hardinge K. Long-term results of Charnley low-friction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75:616-23.
22. Keener JD, Callaghan JJ, Goetz DD, Pederson DR, Sullivan PM, Johnston RC. Twenty-five-year results after Charnley total hip arthroplasty in patients less than fifty years old: a concise follow-up of a previous report. *J Bone Joint Surg Am* 2003;85:1066-72.
23. Sochart DH, Porter ML. The long-term results of Charnley low-friction arthroplasty in young patients who have congenital dislocation, degenerative osteoarthrosis, or rheumatoid arthritis. *J Bone Joint Surg Am* 1997;79:1599-617.
24. Rosenberg WW, Schreurs BW, de Waal Malefijt MC, Veth RP, Slooff TJ. Impacted morsellized bone grafting and cemented primary total hip arthroplasty for acetabular protrusion in patients with rheumatoid arthritis: an 8- to 18-year follow-up study of 36 hips. *Acta Orthop* 2000;71:143-6.
25. Welten ML, Schreurs BW, Buma P, Verdonschot N, Slooff TJ. Acetabular reconstruction with impacted morselized cancellous bone autograft and cemented primary total hip arthroplasty: a 10- to 17-year follow-up study. *J Arthroplasty* 2000;15:819-24.
26. Schreurs BW, Busch VJ, Welten ML, Verdonschot N, Slooff TJ, Gardeniers JW. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86:2385-92.
27. Cil A, Atilla B. Failure of an uncemented non-porous metal-backed prosthesis with augmentation using impacted allograft for acetabular revision. *J Bone Joint Surg Br* 2004;86:1089
28. Hintermann B, Morscher EW. Total hip replacement with solid autologous femoral head graft for hip dysplasia. *Arch Orthop Trauma Surg* 1995;114:137-44.
29. Busch VJ, Gardeniers JW, Slooff TJ, Veth RP, Schreurs BW. Favourable long-term results from cemented total hip arthroplasty combined with acetabular bone impaction grafting in patients under the age of 50. *Ned Tijdschr Geneeskd* 2007;151:1935-40.

Chapter 8

The outcome of a large cohort of 343 consecutive hip arthroplasties in patients under 50 years and the outcome of their revisions

D.C.J. de Kam
J.W.M. Gardeniers
R.P.H. Veth
B.W. Schreurs

Submitted.

Summary

Background. Surgeon's always must take into account that a primary total hip arthroplasty (THA) in a young patient will be revised in the future, this because of the long life expectancy of young THA patients and the limited durability of prosthetic implants in these patients. Therefore we would like to accentuate the revisability of a primary THA in this specific and high demanding patient population.

Methods. 343 consecutive THA in 270 patients under the age of 50 years were evaluated. We also assessed the results of the revised THA (n=53) within the same population. Clinical, radiographical and survival of primary and revision THA were evaluated.

Findings. With no patient lost during follow-up, 53 primary hips were revised after a mean follow-up of 8.9 (range 2.0-19.3) years. Survival with endpoint revision for any reason of either component was 86% after 10 years for primary THA. The average follow-up of the revisions of this population was 4.2 (range 0.1-14.8) years and 3 hips needed a repeat revision. Survival was 91% after 5 years for the revision THA. As well after primary as revision THA showed good clinical outcome.

Interpretation. Cemented implants in young patients show satisfying results as well in primary as revision THA with good survival and clinical outcome. Keeping in mind that the young patient will outlive their primary THA, the primary has to be revisable and the results of the revision THA must be as good as the primary THA. Bone defects in primary and revision THA can be successful managed with impacted bone grafts, without the need for augments, cages or larger implants.

Introduction

The success of total hip arthroplasty (THA) started in the 1960s and early 1970s and are mainly attributed to the investigations of Sir John Charnley, which included the use of cement in combination with low-friction arthroplasty based on the articulation of a metal head with a polyethylene cup.[1] Restoration of joint movement, relief of pain, and full participation in normal daily activities is achieved with the replacement of a restricted hip joint due to end-stage hip disease. This approach is so successful that the total hip arthroplasty is cited as the operation of the last century.[2]

However, long-term survival data of total hip arthroplasties in younger patients are still inferior to the survival data in patients who are over 70 years at the moment of surgery and especially patients who are younger than 50 years at the moment of surgery are very challenging. These patients often have secondary osteoarthritis due to an underlying hip disease, which is frequently accompanied with acetabular bone stock loss. In these cases with acetabular bone stock loss, creating a stable position of the cup is more difficult. In addition, these younger patients have higher activity levels putting increased demands on their hip implants. These factors limit the long term survival of their hip arthroplasties.

For these younger patients, there is a clear need to use reconstruction techniques and hip implants with a proven long-term survival rate.[3] However, even if the techniques and implants are chosen based on these criteria many patients will face a revision of their prosthesis during their living as the life expectancy of the patients is longer than the survival of their hip implants. For these younger patients, in addition to the outcome of their primary implant there is also a need to have outcome data of these subsequent revisions. The question in these young patients is if we can keep them mobile for longer periods. However, these data are not available in literature so far.

For more than 30 years we use standardized approach in all patients under 50 years who have osteoarthritis of the hip.[4] We use always a cemented total hip prosthesis. In cases of acetabular bone stock we always have reconstructed this defect using a biological attractive technique by a bone impaction grafting in combination with cemented cup.

If during the follow-up a revision was needed we again used a standard protocol. At revision most failed hips arthroplasties had bone stock loss, both on the femoral and acetabular side due to the loosening process. We always used a cemented hip prosthesis for revision surgery in all cases. However, in case of bone defects observed at revision surgery, these were reconstructed first with bone impaction grafting on both the acetabular and femoral side.[5-7]

In the current unique study we will present the outcome of 343 consecutive total hip arthroplasties implanted in 270 patients in the period 1988-2004 who were all younger than 50 years at the moment of surgery. We will present the long term survival data of this cohort. In addition we will also present the outcome of all failed hip arthroplasties of this cohort after their revisions of this cohort, which are unique data in literature.

Methods

Study group

Retrospectively, we reviewed the prospectively collected data of all consecutive patients (270 patients, 343 hips) who had a primary cemented THA at our department between 1988 and 2004 and who were younger than 50 years at the index surgery. All indications and all patients were included. No patient was lost to follow-up. All THAs had a cemented femoral stem and a cemented acetabular polyethylene cup, a totally cemented total hip was the only technique we used. Mean age at index surgery was 38.3 years (range, 16-49 years). According to the classification of the American Association of Orthopedic Surgeons (AAOS) for acetabular defects[8], 35 (10.2%) hips had a segmental defect (type I, rim or wall missing), 80 (23.3%) a cavitar defect (type II, volumetric defect with intact walls and rims), 41 (12.0%) a combined segmental and cavitar defect (type III), and 2 (0.6%) hips a bony ankylosis (type V). All acetabular bone defects were reconstructed

Table 1. Primary diagnosis for primary THA.

Diagnosis	Number of cases
Developmental dysplasia of the hip	82
Corticoid steroid induced avascular necrosis	72
Rheumatoid arthritis	51
Posttraumatic osteoarthritis	17
Primary osteoarthritis	16
Coxitis	15
Perhtes' Disease	14
Avascular necrosis of unknown origin	14
Protrusio acetabuli	11
Posttraumatic avascular necrosis	10
Epiphysiolysis	10
Epiphisar dysplasia	9
Bechterew's disease	6
Morquio's disease	4
Polycystic hip disease	2
Fusion of the hips of unknown origin	2
Osteogenesis imperfecta	2
Alcohol induced avascular necrosis	2
Achondroplasia	1
Osteopretrosis	1
Pseudohypoparathyroidism	1
Synovitis Villonodularis Pigmentosa	1
Total	343

with the bone impaction grafting method and this technique was used in 155 cases (45.2%).[4,5] Primary diagnoses were mainly developmental dysplasia of the hip (23.9%), corticosteroid induced avascular necrosis (20.9%) and rheumatoid arthritis (14.9%) (Table 1).

Surgical technique at the primary total hip

All but one operation were performed using a posterolateral approach, in one case an anterolateral approach was used. After resection of the femoral head, the acetabulum was prepared and all cartilage and cysts were removed. If no acetabular defects were seen multiple drill holes were made to facilitate the intrusion of bone cement and the acetabulum was washed. In case of bone defects, segmental defects of the acetabular rim and/or medial wall are first reconstructed with flexible metal wire meshes, which are trimmed and adapted with special scissors and clamps to contain the defect entirely, and fixed with several self-tapping screws (Stryker-Howmedica, Newburry, United Kingdom) (Figure 1A). After creating containment with the wire meshes, only a cavitary defect remains. Sclerotic areas are perforated with multiple small drill holes to enhance better vascularisation of the graft. The socket is rinsed with pulse lavage and trabecular bone chips of 0.7–1.0 mm are placed and tightly impacted with specially designed impactors (Figure 1B-C). Multiple layers of graft are impacted until the defect is completely filled. The bone chips are made of autograft from the resected femoral head and when more bone is needed bone chips were made of fresh frozen human femoral head allografts obtained from a bone bank. The femoral heads are morselized with a special bone mill or by hand with a rongeur. The impactors increase in size and the size of the last impactor used corresponds to the size of the polyethylene cup with its cement layer. We tried to reconstruct the anatomical position of the centre of rotation with the transverse ligament as reference. Vacuum-mixed cement loaded with antibiotics was used and the cement

was pressurized into the trabecular bone in hip without bone defect and into the graft reconstruction is case of a bone reconstruction by bone impaction grafting. Finally a full polyethylene cup is placed and held in position with a pusher until the cement is polymerized (Figure 1D). Before 1989, we used Palacos bone cement (Merck, Darmstadt, Germany); from 1989 forward, we used Surgical Simplex (Stryker-Howmedica, Newburry, UK). The bone impaction grafting technique has been described in detail in the literature.[4,5,9] The femoral component was also inserted with a third-generation cementing technique that included pulse lavage, a distal intramedullary femoral plug, vacuum-mixed cement, and pressurizing the cement with a cement gun and seal.

Implants used

During the studied time interval we used several kinds of implants. All implants were fully cemented and the cups used are made of conventional polyethylene. Only cobalt-chrome heads were sued. On the acetabular side we used 143 (42%) Exeter/Contemporary cups (Stryker Howmedica, Newbury, UK), 153 (45%) Charnley/Elite cups (DePuy, Leeds, UK), and 47 (14%) Müller/Allopro cups (Sulzer, Winterthur, Switzerland). As femoral component we used in 186 (54%) cases an Exeter stem, in 142 (36%) cases a Charnley/Elite stem and in 33 (10%) cases a Müller stem. The inner diameter of the cup was in 26 cases 22.2mm (8%), 28mm in 279 hips (81%) and 32mm in 38 cases (11%).

Postoperative treatment

Patients received antibiotics (cefazolin) for 24 hours to prevent infections. Postoperatively, all patients received thrombosis prophylaxis with low-molecular-weight heparin for 6 weeks or, before 1999, with oral anticoagulants for 3 months according to our postoperative protocol. To prevent heterotopic ossifications, we prescribed

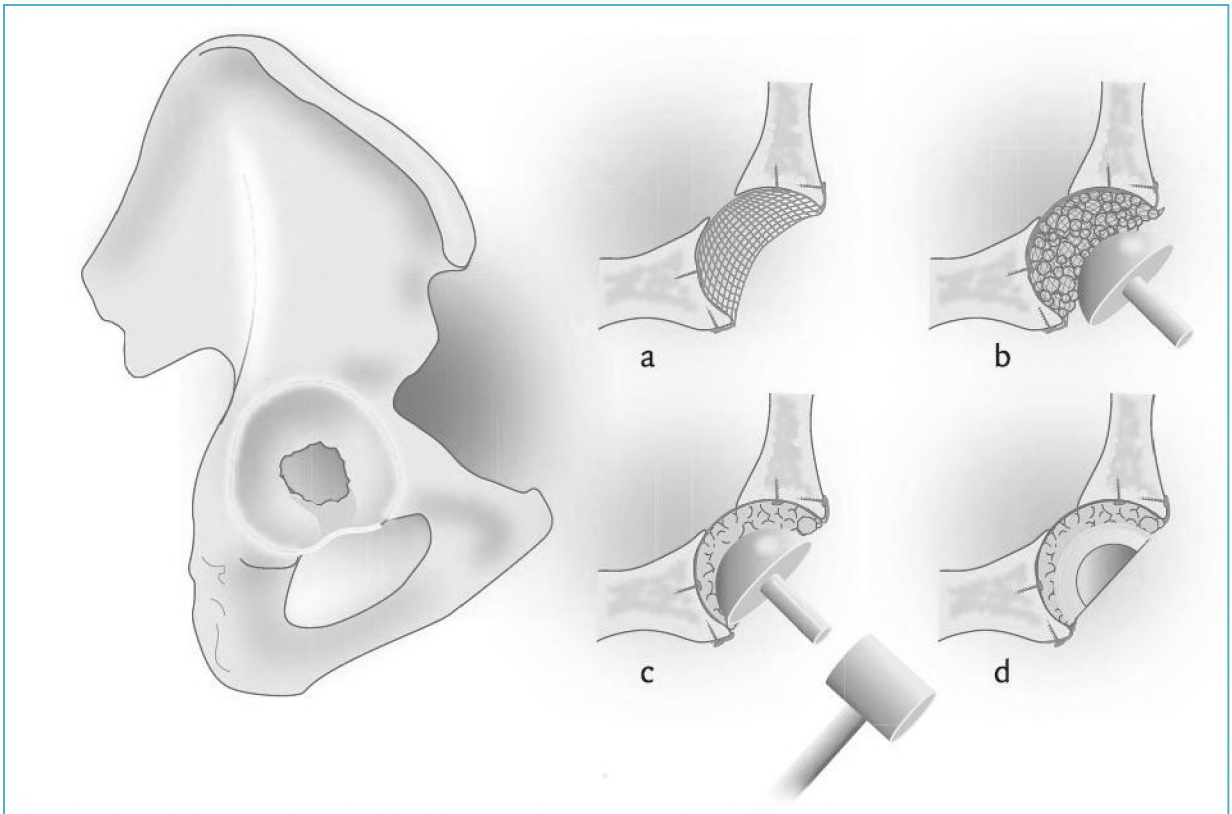


Figure 1. The reconstruction of acetabular defects with bone impaction grafting
Reconstruction of the defects with wire meshes (a), placement of the morselized bone grafts (b), impaction of the bone grafts (c), and the final result with a cemented polyethylene cup (d).[29]

nonsteroidal anti-inflammatory drugs (NSAIDs) for 7 days. When NSAIDs were contraindicated, postoperatively one dose (7 Gy) of radiotherapy was given.

The mobilization protocol was related to the extent of the reconstruction. Patients with simple minor cavitary defects were mobilized after 2 days. In case of extended reconstructions 10% partial weight bearing was allowed for 6 weeks and 50% for another 6 weeks before full weight bearing was allowed. Patients with extensive reconstructions using several femoral heads had a bed rest up to 6 weeks to facilitate some graft stability before weight bearing mobilization.

Surgical technique at the revision total hip

In all cases with a failed cemented total hip, a work-up was performed to diagnose a possible septic loosening. In case of septic loosening we used a 2 stage approach with removal of the implant and all cement. Based on the cultures patients were treated with antibiotics for 3 months and next a reimplantation was planned.

In all other cases a one stage revision was performed. First the implant was removed including the cement, than a new cemented implant was inserted. However, if there was bone stock loss on both the femoral as the acetabular side this was reconstructed with impacted bone grafts first. Segmental defects of the acetabulum and femur were reconstructed with metal wire meshes remaining a contained cavitary defect. Trabecular bone chips of 0.7-1.0 cm are placed into the defect and tightly impacted with specially designed impactors into the acetabulum. We used the same reconstruction technique for the acetabular side in both primary and revision THA in case of acetabular defects. On the femoral side, bone chips of 0.3 to 0.5 cm were impacted with specially designed femoral metal impactors. The bone chips are made of fresh frozen human femoral head allografts obtained from a bone bank. The femoral heads are morselized with a special bone mill or by hand with a rongeur. Next again a cemented implants was inserted. For after treatment we follow the same protocol as had been followed in the primary cases.

Clinical and radiographical analysis

Routine follow-up visits were scheduled after 6 weeks; 3, 6, and 12 months; and yearly or biennial thereafter. Clinical outcome was evaluated with several questionnaires: the Harris Hip Score (HHS)[10], the Oxford Hip Questionnaire Score (OHQS, since 1998)[11]and Visual Analogue Scales (VAS) assessing pain at rest, pain during physical activities and satisfaction (for pain on a scale from 0 (no pain) to 100 (unbearable pain). Clinical questionnaires were obtained by independent researchers at our out-patient clinic. For review, all medical files and questionnaires were evaluated.

A clinical failure was defined as the removal or replacement of one or more components of the THA for any reason. Anteroposterior and lateral radiographs of the THA were obtained and analyzed for radiographical analysis. All radiographs were evaluated on: position of cup, stem and meshes, incorporation of the graft, migration of either component, polyethylene wear according to Dorr et al.[12], and radiological loosening. Radiological loosening/failure is defined as demarcation in two or three zones around the acetabular component of 2 mm or greater, progressive demarcation, component migration of 3 mm or greater, component tilting of 5° or greater, and/or cement or prosthesis fracture. Radiological failure of the stem was defined according to the definitions of Harris et al..[13]

Statistical analysis

We used Kaplan-Meier analysis to calculate the cumulative survival (time to revision) of both the primary hip as well as of the revised hip implant until re-revision. The end points were: (1) revision for any reason; (2) revision for any reason excluding infections; and (3) revision for aseptic loosening. To test any significant differences, the Student t-test or the Chi-Square test is used after checking for normal distribution. All calculations are made with SPSS 16.0. A p-value of <0.05 was considered significant.

Results

Primary THA

All 343 hips in 270 patients were available for evaluation; no patient was lost during follow up. However, in 3 patients a recent radiograph was missing for the radiological evaluation, but based on a telephone interview, in all 3 patients the hip was clinically functioning well. The mean follow-up at review of the 343 hips was 8.9 years (range, 2.0-19.3 years). During follow-up 24 patients died (35 hips), all data until death were available and are used for analysis. Of these 35 hips of deceased patients, 3 were revised. Of the whole group of 343 hips, 53 hips were revised during follow-up.

Clinical outcome of primary THA

Clinical outcome scores improved significantly after surgery. The median HHS improved from 50 preoperatively (mean 49.1; range, 2-82; n=175) to 93 (mean 86.0; range 9-100; n=270) postoperatively (paired t-test: $p < 0.001$). The median OHQS improved from 38 (mean 38.0; range 12-57; n=48) to 16 (mean 19.0; range, 12-55; n=262) postoperatively (paired t-test: $p < 0.001$). The median VAS satisfaction postoperatively was 90 (mean 85.5; range 0-100; n=259). The median VAS pain at rest and pain during physical activities were respectively 0 (mean 8.3; range 0-90; n=266) and 0 (mean 18.2; range 0-100; n=266).

Revisions of primary THA

Fifty-three of 343 hips (16%) were revised after a mean of 7.1 year (range, 0.01-18.4 years) after the primary THA. Reasons for revision were: aseptic loosening (26), septic loosening (13), recurrent dislocations (9), traumatic loosening (2), neuropathy of the sciatic nerve due to overstretching of this nerve after a reconstruction of a high hip center (1), and fracture (2). In 25 cases both the cup and stem were revised, in 21 cases the cup, in 5 cases the stem, and in 2 cases only the femoral head was exchanged (Table 2).

Radiological evaluation of all radiographs showed that most hips were radiographical stable, but 44 cases of the 343 hips were radiographical loose according to the used definitions. Revision of one or more components was performed in 36 of the 44 cases. The average wear of the non-revised cups was 0.09 mm/yr and the wear of the revised cups was 0.22 mm/yr (independent t-test: $p < 0.001$).

Survival analysis of primary THA

Survival analysis of all 343 hips with endpoint revision for any reason of either component showed a survival of 86% after 10 years (Table 3, Figure 2). Survival of the

Table 2. Overview of all revisions of Primary THA and Re-revisions of revision THA.

Reason for (re-)revision	Number of cases	Mean time till revision (range) in years
Primary THA		
Aseptic loosening	26	8.9 (1.1-18.4)
Septic loosening	13	5.0 (1.3-12.9)
Recurrent dislocations	9	3.7 (0.01-11.4)
Fracture	2	8.5 (6.6-10.4)
Traumatic loosening	2	12.6 (10.2-15.0)
Neuropathy	1	2.4
Total	53	7.1 (0.01-18.4)
Revision THA		
Aseptic loosening	1	12.3
Septic loosening	2	1.6 (0.6-2.6)
Total	3	5.2 (0.6-12.3)

stem and cup with endpoint aseptic loosening was 100 and 93% respectively after 10 years. THA with Bone impaction grafting had a survival of 90% (SE 2.8) in contrast to a survival of 82% (SE 3.4) of the cups without an acetabular revision with endpoint revision for any reason (log-rank test, p=0.156) at 10 years. All survival rates are shown in Table 3.

Revision THA

All 53 revision cases in 50 patients were available for evaluation and all but 2 were performed in our department; no patient was lost during follow up. Only one repeat revision (re-revision) was performed in a clinic elsewhere. All clinical and radiographical data were available for review. Indications for revision are mentioned before (Table 2). In 2 cases no revision THA was implanted and a Girdlestone situation was created. Both cases were revised because of infection and there was a persistent chronic infect, so implantation of a new THA was not attractive. 37 of the 45 (82%) cup revisions were reconstructed with impacted bone grafts, and 16 of the 26 (62%) femoral stem revisions were reconstructed with femoral bone impaction grafting. Mean follow-up of the revised hips was 4.2 years (range 0.1-14.8). During follow-up 3 patients died (3 revision THA) all data until death are used for analysis, none have had a repeat revision. Mean age at repeat revision was 46.5 years (range 25.8-65.7).

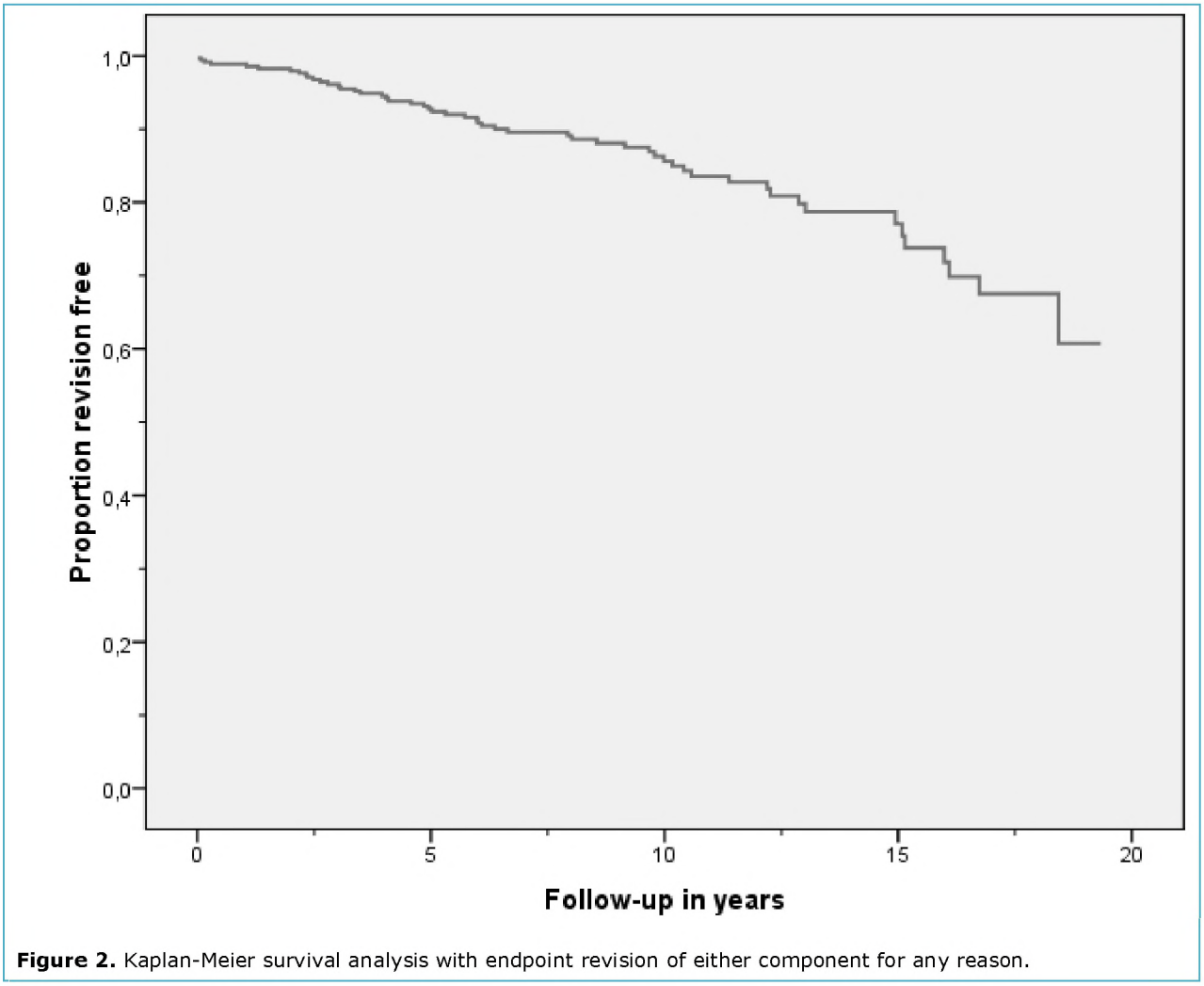


Figure 2. Kaplan-Meier survival analysis with endpoint revision of either component for any reason.

Table 3. Overview of all survival rates classified by the different endpoints.

Component	Any reason		Any reason excl. infections		Aseptic loosening	
	5 years	10 years	5 years	10 years	5 years	10 years
Primary THA						
THA	92.7 (1.5)	85.6 (2.3)	95.0 (1.2)	89.6 (2.0)	97.0 (1.0)	93.0 (1.9)
Stem	97.4 (0.9)	92.1 (1.8)	99.7 (0.3)	96.5 (1.3)	99.7 (0.3)	97.4 (1.2)
Cup	93.6 (1.4)	87.2 (2.2)	95.8 (1.1)	91.3 (1.9)	97.3 (0.9)	93.3 (1.8)
Revision THA						
THA	90.7 (4.5)	nr	100 (0)	nr	100 (0)	nr
Stem	90.7 (4.5)	nr	100 (0)	nr	100 (0)	nr
Cup	90.7 (4.5)	nr	100 (0)	nr	100 (0)	nr

Standard error in brackets, nr = not representative.

Clinical outcome of revision THA

The median HHS after revision was 97 (mean 87.2; range, 24-100; n=43). The median OHQS was 14 (mean 20.1; range 12-51; n=43). The median VAS satisfaction postoperatively was 89 (mean 78.6; range 0-100; n=42). The median VAS pain at rest and pain during physical activities were respectively 0 (mean 15.8; range 0-80; n=43) and 0 (mean 20.1; range 0-95; n=43).

Re-revisions of revision THA

A repeat revision was necessary in 3 of the 53 revision hips (5.7%). Reasons for repeat revision were: infection (n=2) and aseptic cup loosening (n=1). The re-revisions for septic loosening were revised after 0.6 and 2.6 years. Both cases have had a revision of the primary THA because of septic loosening. One patient have had 4 repeat revisions in total and still functions with a THA, the other patient have had 3 repeat revisions and in the last one a Girdlestone was created because of a persistent chronic infection. The re-revision because of aseptic cup loosening was revised after 12.3 years. The reason for revision of the primary THA was infection, but the intraoperative cultures taken during repeat revision were negative. During repeat revision the acetabulum was reconstructed with bone impaction grafting and the cup was replaced.

Survival analysis of revision THA

Survival analysis of all 51 revision THA with endpoint revision for any reason of either component showed a survival of 91% after 5 years. Survival of the stem and cup with endpoint aseptic loosening was both 100. All survival rates are shown in Table 3.

Discussion

In this paper we introduce a new dimension in reporting the outcome of total hip replacements in patients under 50 years. In young patients there is a great need for techniques and implants with proven long term outcomes.[3] Clearly, this is an important strategy to enhance outcome data in younger patients. However, as many of these young patients will still outlive their prosthesis, surgeons should also consider what the outcome is after a revision. If certain types of prosthesis fail with extensive bone stock loss hampering the implantation of a revision implant, the outcome of the inevitable revisions will be less successful. Therefore, we decided to report a large cohort of consecutive total hip arthroplasties and the outcome of the subsequent revisions of the failed implants.

The original cohort of 343 hip prosthesis in 270 patients is quite unique as we are one of the few centers worldwide who always inserts cemented implants in all patients and at all ages. Also we have used one biological approach in these young patients as in all

cases with acetabular bone stock loss, a reconstruction with impacted bone grafts. The follow-up is complete for all patients which make our conclusions reliable.[14] In this multisurgeon single institution study, no cases were excluded and as a referral centre we accept all cases. Also, it is remarkable that almost every revision is performed in our centre. In all revisions we again used the same technique and again cemented implants. With this biological approach we try to reconstruct the bone loss often seen at revisions. Using this technique we prevent the use of larger implants, a technique often used in revision surgery. We think that especially in young patients, one has always to bear in mind the next hip revision and how to facilitate this future problem.

The outcome of the primary cemented implants following this treatment strategy is satisfying, with endpoint revision for any reason showing a survival at 10 years of 86%. This is comparable to other studies.[15-21] Of the 343 hips implanted 13 (3.7%) ended in a septic loosening. However of these 13 infections 12 occurred more than 2 years after implantation and should be considered as heamotogenic infects. Most of these patients had rheumatoid arthritis and were using immunosuppressive drugs. The outcome of both the femoral component as well as the acetabular component with endpoint aseptic loosening at 10 years is excellent.

The most interesting part of this study is the outcome of the failed prosthesis. At final follow-up, only 2 of the 343 total hip arthroplasties resulted in a final Girdlestone situation, both for infection. In fact, these were not reimplantated due to persisting signs of infection. The outcome of the 51 revisions performed within this cohort was 91% survival at 5 years with endpoint a re-revision. There were 3 re-revisions. However, 2 of the 3 failures were septic failures and were originally revised for the indication of septic loosening, so these 2 cases should be considered as failed treatments of previous infections. Excluding these 2 septic failures, only one of the 49 revisions had a re-revision and this was a re-revision for an aseptic cup failure at 12 years after the revision. At 5 years the survival of the revised hips is 100% with endpoint aseptic loosening. There are only a few reports of the outcome of revision THA in young patients. Strömberg et al.[22] reported a survival of 76% after 8 years with endpoint revision for aseptic loosening of either component in 70 revision THA in patients under the age of 55. Other reports about revision THA in young patients are only about the acetabular component. Comba et al.[23] reported a survival of 89% after 7.2 years of the acetabular component with endpoint revision for any reason in a study about 30 revision THA. These results are comparable to those of Raut et al..[24] In this study of 87 revision THA in patients under 56 years, a survival of 90% was seen of the acetabular component with the same endpoint and 67% of the patients had an excellent clinical assessment. The results of the revision THA in our population seems to be promising, but longer follow-up is necessary.

As pointed out by McAuley et al. especially in young patients there is a need for total hip implants with proven long-term outcomes. Using the NICE criteria that at least a survival of 90% or more is needed at 10 years with revision for any reason of either component, it is possible to select implants and prostheses from literature that fulfill these criteria.[25] So far, the nowadays very popular uncemented implants often used in young patients are not represented in this selection. Also our study fails to pass the NICE criterion as our survival at 10 year was only 86%. However, we have pointed out that with this protocol using cemented implants it is possible to revise a failed implant with again a satisfying clinical outcome and a very acceptable midterm survival rate. In young patient we think that this new dimension of reporting the survival of THA is essential to prove that with a certain implant philosophy it is possible to keep these young patients mobile, also on the long term.

References

1. Charnley J. Arthroplasty of the hip. A new operation. *Lancet* 1961; 7187: 1129-32.
2 Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007;27; 370:1508-19.
3. McAuley JP, Szuszczewicz ES, Young A, Engh CA, Sr. Total hip arthroplasty in patients 50 years and younger. *Clin Orthop Relat Res* 2004;418:119-25.
4. Schreurs BW, Busch VJ, Welten ML, Verdonschot N, Slooff TJ, Gardeniers JW. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86(11):2385-92.
5. Schreurs BW, Bolder SB, Gardeniers JW, Verdonschot N, Slooff TJ, Veth RP. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented cup. A 15- to 20-year follow-up. *J Bone Joint Surg Br* 2004;86(4):492-7.
6. Schreurs BW, Arts JJ, Verdonschot N, Buma P, Slooff TJ, Gardeniers JW. Femoral component revision with use of impaction bone-grafting and a cemented polished stem. *J Bone Joint Surg Am* 2004;86(11):2385-92.
7. Halliday BR, English HW, Timperley AJ, Gie GA, Ling RS. Femoral impaction grafting with cement in revision total hip replacement. Evolution of the technique and results. *J Bone Joint Surg Br* 2003;85(6):809-17.
8. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG, et al. Classification and management of acetabular abnormalities in total hip arthroplasty. *Clin Orthop Relat Res* 1989;243:126-37.
9. Schreurs BW, Gardeniers JW, Slooff TJ. Acetabular reconstruction with bone impaction grafting: 20 years of experience. *Instructional Course Lectures* 2001;50:221-8.
10. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 1969;51(4):737-55.
11. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br* 1996;78(2):185-90.
12. Dorr LD, Wan Z. Comparative results of a distal modular sleeve, circumferential coating, and stiffness relief using the Anatomic Porous Replacement II. *J Arthroplasty* 1996;11(4):419-28.
13. Harris WH, McCarthy JC, Jr., O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg Am* 1982;64(7):1063-7.
14. Murray DW, Britton AR, Bulstrode CJ. Loss to follow-up matters. *J Bone Joint Surg Br* 1997;79(2):254-7.
15. Chiu KY, Ng TP, Tang WM, Poon KC, Ho WY, Yip D. Charnley total hip arthroplasty in Chinese patients less than 40 years old. *J Arthroplasty* 2001;16(1):92-101.
16. Crowther JD, Lachiewicz PF. Survival and polyethylene wear of porous-coated acetabular components in patients less than fifty years old: results at nine to fourteen years. *J Bone Joint Surg Am* 2002;84(5):729-35.
17. Joshi AB, Porter ML, Trail IA, Hunt LP, Murphy JC, Hardinge K. Long-term results of Charnley low-friction arthroplasty in young patients. *J Bone Joint Surg Br* 1993;75(4):616-23.
18. Sochart DH, Porter ML. The long-term results of Charnley low-friction arthroplasty in young patients who have congenital dislocation, degenerative osteoarthrosis, or rheumatoid arthritis. *J Bone Joint Surg Am* 1997;79(11):1599-617.
19. Garcia-Cimbrelo E, Cruz-Pardos A, Cordero J, Sanchez-Sotelo J. Low-friction arthroplasty in patients younger than 40 years old: 20- to 25-year results. *J Arthroplasty* 2000;15(7):825-32.
20. Singh S, Trikha SP, Edge AJ. Hydroxyapatite ceramic-coated femoral stems in young patients. A prospective ten-year study. *J Bone Joint Surg Br* 2004;86(8):1118-23.
21. McCullough CJ, Remedios D, Tytherleigh-Strong G, Hua J, Walker PS. The use of hydroxyapatite-coated CAD-CAM femoral components in adolescents and young adults with inflammatory polyarthropathy: ten-year results. *J Bone Joint Surg Br* 2006;88(7):860-4.
22. Stromberg CN, Herberts P. Cemented revision total hip arthroplasties in patients younger than 55 years old. A multicenter evaluation of second-generation cementing technique. *J Arthroplasty* 1996;11(5):489-99.
23. Comba F, Buttaro M, Pusso R, Piccaluga F. Acetabular revision surgery with impacted bone allografts and cemented cups in patients younger than 55 years. *International orthopaedics* 2009;33(3):611-6.
24. Raut VV, Siney PD, Wroblewski BM. Revision of the acetabular component of a total hip arthroplasty with cement in young patients without rheumatoid arthritis. *J Bone Joint Surg Am* 1996;78(12):1853-6.
25. Guidance on the selection of prostheses for primary total hip replacement. London. *National Institute for Clinical Excellence*; 2003.

Chapter 9

Cemented Revision Hip Arthroplasty in Patients Younger Than 60 Years

D.C.J. de Kam
M. van Heumen
J.W.M. Gardeniers
R.P.H. Veth
B.W. Schreurs

Submitted.

Abstract

Background. These days, total hip arthroplasties (THA) are more implanted in young patients. Due to the expected lifespan of a THA and the life expectancy of young patients, a future revision is inevitable. Indirectly increasing the number of revisions in these patients. Therefore we evaluated the results of revision THA in patients under the age of 60 years. However, we used a unique protocol in which we used in all cases of acetabular and/or femoral bone deficiencies reconstruction with bone impaction grafting.

Methods. To determine the mid- to longterm results of cemented revision total hip arthroplasties in patients under the age of 60, all clinical data and radiographs were analysed of patients operated between 1992 and 2005. Patients with multiple previous revisions were also included. Only cemented components were used. During this period 146 consecutive revision total hip arthroplasties were implanted in 129 patients. This included 124 cup and 106 stem revisions. The average age at index surgery was 47 years. No case was lost. Mean follow-up was 7.6 (range, 2.0-16.7) years.

Results. Outcome of clinical questionnaires improved significantly after revision THA. During follow-up 19% (28 hips) needed a repeat revision (aseptic loosening 13, septic loosening 10, recurrent dislocations 2, traumatic loosening 2, and abductor contracture 1). Seven of 146 cases (4.8%) ended finally in a permanent Girdlestone. Seventeen (14%) of the 124 cups were radiographically loose, 11 were revised. Four (4%) of the 106 stems were radiographically loose, 2 were revised.

The 10-years survival was 78% with endpoint revision for any reason and 87% with endpoint revision for aseptic loosening. 28 hips needed repeat revision after the index revision. No significant differences in survival were found looking at the different indications for revision

Conclusions. The survival of cemented revision THA in patients under the age of 60 is satisfying. Reconstruction of acetabular and femoral bone deficiencies with bone impaction grafting is a promising and biological attractive technique in this young and high demanding population and enhances the revisability of a THA.

Level of Evidence. Level III, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

The use of total hip arthroplasty (THA) in young patients is increasing.[1] Surgeons are less reluctant to implant these devices because of the satisfying results in older patient populations. This trend is encouraged by the orthopaedic industry with new implant designs and newer bearing surfaces claiming better long-term results. But because of the higher activity levels and secondary osteoarthritis higher revision rates of THA in young patients are seen. With the increased number of primary implants and the higher revision rates, the incidence of revision THA in young patients is also increasing. In most of the times, loosening of THA involves bone stock loss. Young patients often have already acetabular deficiencies before primary THA due to secondary osteoarthritis. A failure of the primary THA can result in even larger acetabular bone stock loss, making these revisions sometimes very difficult. Femoral revisions have also to deal with femoral bone stock loss.

Several techniques have been described for the revision of a primary THA with varying results like a high hip center, cages, bulk grafts, and bilobed or augmented cups.[2-10] Each technique has its own advantages and disadvantages. Despite the extensive reports of the different techniques used in revision THA, the reports about outcome of revision THA in young patients (<60) is very lacking.

In 1979 Slooff et al. introduced the use of bone impaction grafting in hip revision surgery[11] and several groups have reported good results with this technique during primary and revision THA.[12-17] Gie et al. improved the reconstruction technique of femoral defects with impacted bone grafts.[18] This technique is very attractive for revision THA in young patients, because of its potential to biological restore bone deficiencies.[19,20] In case of acetabular or femoral deficiencies, we have always used bone impaction grafting during revision THA at our clinic.

The purpose of this study is to report the clinical results, repeat revisions, radiographic results, and survival of a population consisting of patients younger than 60 years old who underwent a cemented revision of one or more components of their THA.

Materials and Methods

We retrospectively reviewed all patients who have had a revision THA in our department between January 1992 and December 2005, and who were younger than 60 years at index surgery. Previous revisions or other hip operations were no exclusion criteria. THA implanted because of oncologic indications were excluded. We reviewed all patients' records and radiographs for clinical and radiological data. Failure was defined as the removal or repeat revision of the revised component(s). In this period 146 revisions in 129 patients were performed. Of the 146 revisions, 76 were performed on the left side and 71 on the right side; 13 patients have had a bilateral revision. Seventy-four patients

Table 1. Indications for index revision surgery and component(s) revised.

Reason	THA	Stem	Cup	Head	Total
Aseptic loosening	56	13	25	0	94
Septic loosening	26	1	2	0	29
Recurrent dislocations	1	3	6	2	12
Traumatic loosening	1	0	3	0	4
Heterotopic ossifications	2	0	0	0	2
Abductor contracture	1	0	0	0	1
Fracture	0	1	0	0	1
Mismatch	0	0	0	1	1
Neuropraxia	0	0	1	0	1
Periprosthetic fracture	0	1	0	0	1
Total	87	19	37	3	146

THA = both cup and stem revised

were female and 55 male. Four patients have had two revisions on the same side of different components during the research period. The mean age at index surgery was 47.3 years (range, 25-59 years). The mean follow-up was 7.6 years (range, 2.0-16.7 years). During follow-up 10 patients (12 revisions) died, two of these patients (2 hips) have had a repeat revision after respectively 1.1 and 2.2 years. All patients who died were followed on a regular basis and their data included. No patient was lost during follow-up and no data of any patient was missing.

Indications for revision THA were mainly aseptic loosening (n=94), septic loosening (n=29) and recurrent dislocations (n=12) (Table 1). In 87 cases all components, in 37 cases only the cup, in 19 cases only the stem and in 3 cases only the femoral head were revised. The majority of all revisions were performed by or under supervision of two senior faculty orthopaedic surgeons (BWS, JWMG). All approaches were performed posterolateral except one (straight lateral).

Surgical technique

All acetabular deficiencies were reconstructed with impaction grafting using auto- and/or allografts. This technique has been described in the literature in detail.[14,21,22] Segmental bone defects were first reconstructed with wire meshes before the morselized bone graft was impacted and a conventional full polyethylene cup was cemented (Figure 1A-D). Femoral deficiencies were also reconstructed with bone impaction grafting, details of this technique are also found in the literature.[18,23-25] We categorized acetabular defects in accordance with the classification system of the American Academy of Orthopaedic Surgeons.[26] In total, 116 of the 124 revised cups (94%) had an acetabular deficiency. Type I segmental deficiencies occurred in 14 hips, Type II cavitary defects in 28 hips, and Type III combined deficiencies in 73 hips. A type IV pelvic discontinuity was present in 1 case. Using impaction grafting we reconstructed all deficiencies, including mild cavitary defects; however most were larger defects. In 61 of the 106 stem revisions femoral reconstruction with bone impaction grafting was performed. As source for the impaction grafting 1 to 5 femoral heads were used. Only cemented components were used. We cemented acetabular and femoral components with a third-generation cementing technique with antibiotic loaded cement. Before 1989, we used Palacos® bone cement (Merck, Darmstadt, Germany); from 1989 on, we used Surgical Simplex® (Stryker Howmedica, Newbury, UK). All patients received antibiotic prophylaxis consisting of 2g cefazolin intravenously after cultures. Other precautionary measures to prevent infections were the use of an operating theatre with laminar airflow and the use of two pairs of sterile gloves.

In the 124 cup revisions we used 58 (47%) Exeter™ Contemporary™ cups with an inner diameter of 28 mm (n = 57) or 22.225 mm (n = 1) (Stryker Howmedica, Newbury, UK), 18 (15%) Charnley®/Elite™ cups with an inner diameter of 22.225 mm (n = 2), 28 mm (n = 15) or 32 mm (n = 1) (DePuy, Leeds, UK), and 48 (39%) Müller/AlloPro cups with an inner diameter of 22.225 mm (n = 2), 28 mm (n = 2) or 32 mm (n = 44) (Sulzer, Winterthur, Switzerland).

For the 106 revised femoral components, we used an Exeter™ stem in 100 cases (94%), a Charnley® / Elite™ stem in 4 cases (4%), and a Müller stem or Waldemar-Link stem (Link, Hamburg, Germany) both in 1 case (1%). All femoral heads used were made of a cobalt-chrome alloy; no ceramic implants were used.

Post operative treatment

Postoperatively, all patients received thrombosis prophylaxis with low-molecular-weight heparin for 6 weeks, or before 1999 with acenocoumarol (the individual dosage regimens regulated with regular coagulation tests), for 3 months. To prevent heterotopic ossification, we used nonsteroidal anti-inflammatory drugs (NSAIDs) for 7 days. Patients with a direct cementation were mobilized under supervision of a physical therapist 1 or 2

(A) Visualisation of the segmental rim defect with the trial socket after acetabular reaming and preparation. A combined (type 3) defect is present.

(B) Reconstruction of the rim with a wire mesh and fixation of this mesh with screws in all corners. The thin medial wall is reinforced with a wire mesh. With the reconstruction of the rim a cavitar defect is remaining.

(C) Impaction of morselized bone grafts with impactors. Multiple layers of grafts are impacted with great force giving a stable reconstruction.

(D) Finally, a full polyethylene cup is cemented onto the impacted bone graft. Note that the defects are fully reconstructed and there is good containment of the cup. The neck of the femoral stem is positioned anterior of the acetabulum during the cup revision.

Figure 1. Acetabular reconstruction with bone impaction grafting.

days postoperative. Full weightbearing was increased in 2 to 6 weeks with the aid of one or two crutches. The patients who underwent impaction grafting were mobilized according to a modified protocol; in the first 6 weeks, only 10% weightbearing was allowed and then 6 to 12 weeks of 50% weightbearing using two crutches. After 12 weeks, full weightbearing mobilization was allowed. In case of extensive reconstruction of major defects several weeks of bed rest were maintained ranging from 1 to 6 weeks. We used this modified mobilization protocol to ensure graft incorporation before full weightbearing.

Routine followup visits were scheduled at 6 weeks; 3, 6, and 12 months; and yearly or biannually thereafter. At our outpatient clinic, student researchers not participating in the treatment performed clinical analysis using the Harris Hip Score (HHS),[27] the Oxford Hip Questionnaire Score (OHQS; since 1998),[28] and Visual Analogue Scales for pain during rest and physical activity on a scale from 0 (no pain) to 100 (unbearable pain) and for satisfaction on a scale of 0 (not satisfied at all) and 100 (complete satisfaction).[29-33]

Radiological analysis
All anteroposterior pelvis and lateral radiographs of all hips were analyzed on a consensus basis by two of the authors (DCJDK, BWS). Radiographic evaluation included an assessment of cup position, loosening of the acetabular component, polyethylene wear, presence of osteolysis, structural quality of the bone graft, application and position of the meshes, migration, heterotopic ossification, and fracture of the cement, mesh, or prosthesis. Radiolucent lines and osteolysis were recorded according to the three acetabular zones as described by DeLee and Charnley.[34] Radiographic loosening was defined as demarcation in two or three zones around the acetabular component of 2 mm or greater, progressive demarcation, component migration of 3 mm or greater, component tilting of 5° or greater, and/or cement or prosthesis fracture. We determined cup migration (> 3-mm shift in any direction or > 5° tilting) in relation to the interteardrop line instead of the Kohler line.[35] Position of the cup of 45° ± 10° was considered normal.[36] We calculated polyethylene wear using the method of Dorr and Wan.[37] Radiographic evaluation included an assessment of loosening of the femoral component, stem position, osteolysis, rounding-off of the calcar, migration, cortical hypertrophy and/or atrophy, and cement fractures. Radiolucent lines and osteolysis were recorded in accordance with the 7 femoral zones described by Gruen et al..[38] A valgus or varus position of the femoral stem was evaluated as normal within a 3° margin. Loosening of the femoral component was analyzed by the criteria of Harris et al..[39] Subsidence of 2mm or more was registered abnormal as described by Loudon et al..[40] All measurements were corrected for magnification. We classified heterotopic ossification according to the system of Brooker et al..[41] Graft incorporation was defined as the presence of the crossing of trabecular bone on the bone-graft interface on the radiographs.

Statistical analysis
We calculated Kaplan-Meier curves to study the survival (time to revision). The end points were: (1) revision for any reason, (2) revision for any reason excluding infections, (3) revision for aseptic loosening, and (4) radiographic signs of THA loosening. Differences in outcomes between the groups were determined with the Student's t-test (continuous variables after checking for normal distribution) or the chi square test (nominal variables). Differences in survival were calculated with the log-rank test. All statistical analyses were performed with SPSS 16.0.

Results

Outcome of clinical questionnaires
The outcome of the Harris Hip Score improved significantly after surgery (paired sample t-test, $p < 0.001$), but the difference in the Oxford Hip Questionnaire pre and postoperative was not significant (paired sample t-test, $p = 0.324$) (Table 2). The postoperative experienced pain was low and patients were satisfied. Patients who needed a repeat revision showed no significant increase of the HHS and OHQS at final follow-up with a median preoperative score HHS and OHQS of 57 and 42 versus 86 and 23 postoperative, respectively (paired sample t-test, $p = 0.122$ and $p = 0.138$).

Repeat revisions
Nineteen percent of all revisions needed a repeat revision (Table 3). Mean time to repeat revision was 5.6 years (range, 0.6-14.1 years). Reasons for repeat revision were: aseptic loosening (13), septic loosening (10), recurrent dislocations (2), traumatic loosening (2), and abductor contracture (1). In 17 cases both components, in 3 cases the stem and in 8 cases the cup needed repeat revision. Of the 10 hips needing repeat revision because of septic loosening, 5 were primarily revised for septic loosening. Five cases were converted to a permanent Girdlestone situation (4 infections, 1 traumatic loosening in a patient with no compliance). In 5 cases the repeat revision failed, of these 5 patients 2 cases resulted

in a permanent Girdlestone (Figure 2). Finally, 7 of 146 (4.8%) revisions ended in a permanent Girdlestone.

Table 2. Outcome of clinical questionnaires.

Questionnaire	Without repeat revision (n = 118) Preoperative score	Postoperative score	With repeat revision (n = 28) Preoperative score	Postoperative score
Harris hip score	52 (5-100) (n = 42)	93 (24-100) (n = 102)	57 (45-72) (n = 4)	86 (23-100) (n = 21)
Oxford Hip Questionnaire Score	23 (12-49) (n = 37)	20 (12-51) (n = 103)	42 (26-50) (n = 5)	23 (12-48) (n = 20)
VAS satisfaction	NA	80 (0-100) (n = 102)	NA	80 (10-100) (n = 20)
VAS pain at rest	NA	0 (0–80) (n = 103)	NA	0 (0-70) (n = 20)
VAS pain during physical activity	NA	0 (0-95) (n = 103)	NA	15 (0-85) (n = 20)

Values are expressed as median, with range in parentheses; VAS = visual analog scale; NA = not available.

Table 3. Indications for repeat revision and component(s) revised.

Reason	THA	Stem	Cup	Head	Total
Aseptic loosening	4	2	7	0	13
Septic loosening	10	0	0	0	10
Recurrent dislocations	0	1	1	0	2
Traumatic loosening	2	0	0	0	2
Periprosthetic fracture	1	0	0	0	1
Total	17	3	8	0	28

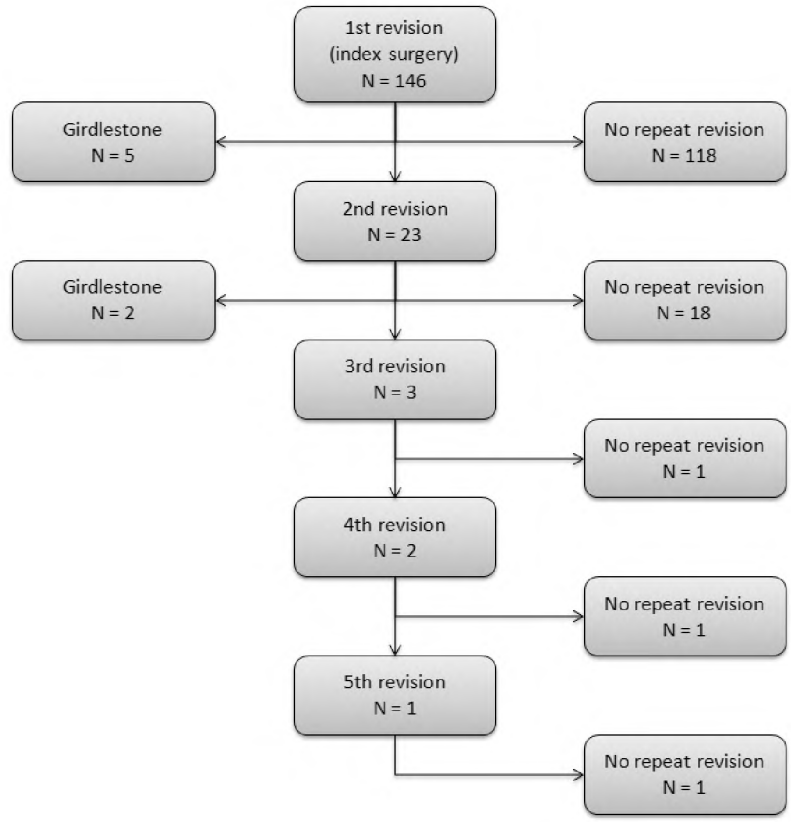


Figure 2. Flowchart about the revisions during follow-up.

Table 4. Radiographical findings of all evaluated revisions (n = 146).

Item		Cups (n=124)		Stems (n=106)
Available for evaluation				
Yes		122		104
No		2		2
Use of BIG				
Yes		116		61
No		8		45
Incorporation of graft				
Yes		109		61
No		4		0
Position				
	>35°	7	Varus (>3°)	15
	35°-55°	101	Neutral	85
	<55°	14	Valgus (>3°)	4
Osteolysis				
None		113		94
Yes		9		10
Cysts				
Yes		0		0
No		122		104
Migration				
No		109		77
Yes		13		27
	Vertical	11	Subsidence	26
	Horizontal	2	Caudal & varus	1
Tilting				
Yes		11		n/a
No		111		
Radiographical loose				
Yes		17		4
No		122		100
Heterotopic ossifications				
Type 1		18		15
Type 2		11		8
Type 3		4		5
Type 4		1		1
None		88		75
Fractures				
	Mesh(fixation)	2	Trochanter	5
	Acetabulum	1	Periprosthetic	1
			Cement	1
Radiolucent lines				
None		98		83
Yes		24		21
Progressive		20		19
Stable		4		2
Wear (mm/yr)				n/a
Without repeat revision		0,11		
Range		(0-1,21)		
With repeat revision		0,14		
Range		(0-0,75)		
Meshes used				n/a
	Medial	16		
	Rim	51		
	Medial & rim	29		
Cortical hypertrophy		n/a	Yes	10
			No	94
Cortical atrophy		n/a	Yes	2
			No	102
Sclerosis		n/a	Yes	0
			No	104
Rounding-off		n/a	Yes	2
			No	102

n/a = not applicable

Results of radiological analysis
Twenty-one (17%) of the 124 revised cups were radiographically loose, 13 of these loose cups have had a repeat revision. Four (4%) of the 106 revised stems were radiographically loose, 2 of these stems have had a repeat revision. Radiographical follow-up was complete in 143 cases. Of 2 deceased patients all radiographs were missing and the THA could not be evaluated radiographically. Analysis of the postoperative radiographs was performed of the 124 revised cups and 106 revised stems (Table 4). Four cups were difficult to evaluate because of the overlap of the metal mesh. Twenty-one cups showed radiolucent lines, 17 were progressive. All but 3 radiolucent lines were on the bone-cement interface. In 110 cases of reconstruction with bone impaction grafting, the graft showed signs of fully incorporation, the graft was lytic in 2 cases. Average wear was 0.12 mm/yr for the cups who did not needed repeat revision, and 0.17 mm/yr for the cups who needed a repeat revision (Independent sample t-test, $p = 0.507$). There was not a significant difference in average wear between the cups which were radiological stable en the radiological loose cups (independent sample t-test, $p = 0.284$).

Results of survival analysis
No differences in survival were found between the THA and cups revised because of aseptic loosening or septic loosening with endpoint revision for all reasons (log-rank test, $p = 0{,}452$ and $p = 0.312$) and endpoint revision for aseptic loosening (log-rank test, $p = 0.258$ and $p = 0.746$). The cumulative survival of all revisions with endpoint revision for all reasons of either component was 78% after 10 years (Table 5). Survival with endpoint aseptic loosening of the THA, cup, and stem was respectively 87%, 91%, and 94% after 10 years (Table 5). Radiographical survival after 10 years with endpoint radiographical loosening was 76.3% (SE 5.7) for the cups and 94.0% (SE 3.1) for the stems.

Discussion

The aim of this study is to report the clinical results, repeat revisions, radiographic results, and survival of a population consisting of patients younger than 60 years old who underwent a cemented revision of one or more components of their THA. Because of the increasing use of primary THA in young patients and the limiting reports of results after revision THA in these young patients.

In our study 19% of all revisions needed a repeat revision. It is well known that age is an important factor for the success of a revision THA. Young patients have a higher risk for recurrent loosening.[43] The main reason for repeat revision was aseptic and septic loosening. It is remarkable that 5 of the 10 repeat revisions for septic loosening were also primarily revised because of an infection. To prevent a recurrence of an infection we performed only 2-stage revisions in the suspicion of infection. A revision THA was only implanted when cultures and lab tests showed no signs of infection. At final follow-up only 7 of 146 cases (4.8%) ended in a permanent Girdlestone and thus in a definitive failure of the THA. This is a low rate and we think it is because of the advantages of the used reconstruction methods. With bone impaction grafting the bone deficiencies are biologically restored, which creates a better position for a future repeat revision and therefore improves the revisability of a THA.[20] Other revision techniques like long distal fixated uncemented implants, bilobed cups, cages or augments do not naturally restore the bone deficiencies.

An additional 6 cups and 2 stems were radiographical loose besides the THA that already needed a repeat revision. With endpoint radiographical loosening the survival of the cups was 82% and 94% for the stems. Raut et al.[44] reported a cup survival of 75% with endpoint radiographical loosening after 6 years. With the use of the so called second-generation cementing techniques, the number of radiographical loose THA en the appearance of radiolucent line is decreased.[45]

The HHS and OHQS improved for patients without repeat revision. This is in line with reported clinical outcome in the literature.[21,42]

Table 5. Kaplan-Meier survival analysis of all revisions with the different endpoints after 10 years.

Component	Number of cases included	Endpoint revision for all reasons	Endpoint revision for all reasons excluding infections	Endpoint revision for aseptic loosening
THA	146	77,5 (4,5)	82,9 (4,4)	86,5 (4,3)
Cup	124	81,5 (4,4)	87,5 (4,2)	91,3 (3,9)
Stem	106	84,0 (4,3)	90,4 (3,9)	93,5 (3,6)

Standard error in brackets

Table 6. Review of the literature about revision THA <60 years.

Item	Current study	Raut et al.**[44]	Strömberg et al.**[43]	Comba et al.*[13]	Thorey et al.[42]	Schreurs et al.*[21]
Number of hips	146	87	70	30	20	19
Number of patients	129	82	68	27	20	18
Number of cups	124	87	48	30	Not included	19
Number of stems	106	Not included	57	Not included	20	Not included
Mean age at index surgery	47,3	44,6	47	44,7	52,7	37,2
(range)	(25-59)	(23-55,9)	(29-55)	(31-54)	(34-58)	(20-49)
Mean follow-up	7,6	6	7	7,2	8	12
(range)	(2,0-16,7)	(1,9-18,1)	(4-10)	(2,8-19)	(5-11)	(3-21)
Survival						
Years of reported survival	10	6	8	7,2	8	10
THA, endpoint all reasons	78%	-	-	-	-	-
THA, endpoint aseptic loosening	87%	-	76%	-	-	-
Stem, endpoint all reasons	84%	-	-	-	95%	-
Stem, endpoint aseptic loosening	94%	-	85%	-	-	-
Cup, endpoint all reasons	82%	90%	-	89%	-	89%
Cup, endpoint aseptic loosening	91%	-	80%	-	-	100%

* = Only patients included with revision because of aseptic loosening, ** = Only patients included with revision because of aseptic loosening and patients with inflammatory diseases excluded.– = Not reported.

Our results of cemented revision THA in young patients are very acceptable. These results are at least comparable or even better compared to those reported in the literature. Only a few studies do report the results of revision THA in patients under the age of 60 years (Table 6). Most of these studies included only patients which were revised because of aseptic loosening instead of all reason for revision.[13,43,44] We found no significant difference in the survival of THA revised because of aseptic or septic loosening. Only one other study evaluated the results of all revisions.[42] In our opinion, none of these studies are complete; often only aseptic survival, mid-term results, or the outcome of one component is reported. Raut et al.[44] studied the outcome of 87 revised cups because of aseptic loosening after a mean follow-up of 6 years. They found a survival of 90% with endpoint revision for all reasons after 6 years. Patients with an inflammatory disease were excluded. Strömberg et al.[43] reported an outcome of 80% after 8 years in a study about 48 cups revised because of aseptic loosening. They excluded patients with an inflammatory disease too. In another study about 30 cups who were revised because of aseptic loosening, a survival outcome of 89% was found after 7.2 years with endpoint revision of the cup for all reasons.[13] When we specially look at

the cups revised because of aseptic loosening (n = 81) in our study a survival is found of 90%, 88%, and 86% after 6, 7, and 10 years with endpoint revision for any reason. The survival of these cups with endpoint revision for recurrent aseptic loosening the survival is 99%, 97%, and 94% after 6, 7, and 10 years. Just one study report the results of uncemented implants in revision THA in young patients. Thorey et al.[42] reported a revision rate of 5% of the uncemented Bicontact stem after a mean follow-up of 8 years with endpoint revision for any reason. No results about cup revisions were given. Schreurs et al.[21] reported the use of bone impaction grafting in acetabular revision THA in young patients before. They found a survival of 89% and 100% with endpoints revision for all reasons and revision for aseptic loosening after 10 years.

As far the authors are aware of, this is the largest and the only study about revision THA in young patients with survival analysis of both components and different endpoints with mid- to long-term follow-up. The survival of cemented revision THA in patients under the age of 60 is satisfying. Reconstruction of acetabular and femoral bone deficiencies with bone impaction grafting is a promising and biological attractive technique in this young and high demanding population and enhances the revisability of a THA.

References

1. Kurtz S, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future Young Patient Demand for Primary and Revision Joint Replacement: National Projections from 2010 to 2030. *Clin Orthop Relat Res* 2009;467:2606–12.
2. Berry DJ, Sutherland CJ, Trousdale RT, Colwell CW Jr, Chandler HP, Ayres D, Yashar AA. Bilobed oblong porous coated acetabular components in revision total hip arthroplasty. *Clin Orthop Relat Res* 2000;371:154-60.
3. Hendricks KJ, Harris WH. Revision of failed acetabular components with use of so-called jumbo noncemented components. A concise follow-up of a previous report. *J Bone Joint Surg Am* 2006;88:559-63.
4. Hooten JP Jr, Engh CA Jr, Engh CA. Failure of structural acetabular allografts in cementless revision hip arthroplasty. *J Bone Joint Surg Br* 1994;76:419-22.
5. Kawanabe K, Akiyama H, Onishi E, Nakamura T. Revision total hip replacement using the Kerboull acetabular reinforcement device with morsellised or bulk graft: results at a mean follow-up of 8.7 years. *J Bone Joint Surg Br* 2007;89:26-31.
6. Kelley SS, Johnston RC, Pulliam I. High hip center in revision arthroplasty. *J Arthroplasty* 1994;9:503-10.
7. Kwong LM, Jasty M, Harris WH. High failure rate of bulk femoral head allografts in total hip acetabular reconstructions at 10 years. *J Arthroplasty* 1993;8:341-6.
8. Schutzer SF, Harris WH. High placement of porous-coated acetabular components in complex total hip arthroplasty. *J Arthroplasty* 1994;9:359-67.
9. Winter E, Piert M, Volkmann R, Maurer F, Eingartner C, Weise K, Weller S. Allogeneic cancellous bone graft and a Burch-Schneider ring for acetabular reconstruction in revision hip arthroplasty. *J Bone Joint Surg Am* 2001;83:862-7.
10. Zehntner MK, Ganz R. Midterm results (5.5-10 years) of acetabular allograft reconstruction with the acetabular reinforcement ring during total hip revision. *J Arthroplasty* 1994;9:469-79.
11. Slooff TJ, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Scand* 1984;55:593-6.
12. Buttaro MA, Comba F, Pusso R, Piccaluga F. Acetabular revision with metal mesh, impaction bone grafting, and a cemented cup. *Clin Orthop Relat Res* 2008;466:2482-90.
13. Comba F, Buttaro M, Pusso R, Piccaluga F. Acetabular revision surgery with impacted bone allografts and cemented cups in patients younger than 55 years. *Int Orthop* 2009;33:611-6.
14. De Kam DCJ, Gardeniers JWM, Hendriks JC, Veth RPH, Schreurs BW. Cemented polyethylene cups in patients younger than 40 years. *Clin Orthop Relat Res* 2009;467:1753-64.
15. Schreurs BW, Bolder SB, Gardeniers JWM, Verdonschot N, Slooff TJJH, Veth RPH. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented cup. A 15- to 20-year follow-up. *J Bone Joint Surg Br* 2004;86:492-7.
16. Schreurs BW, Van Tienen TG, Buma P, Verdonschot N, Gardeniers JWM, Slooff TJJH. Favorable results of acetabular reconstruction with impacted morsellized bone grafts in patients younger than 50 years: a 10- to 18-year follow-up study of 34 cemented total hip arthroplasties. *Acta Orthop Scand* 2001;72:120-6.
17. Ornstein E, Franzen H, Johnsson R, Sandquist P, Stefansdottir A, Sundberg M. Migration of the acetabular component after revision with impacted morselized allografts: a radiostereometric 2-year follow-up analysis of 21 cases. *Acta Orthop Scand* 1999;70:338-42.
18. Gie GA, Linder L, Ling RS, Simon JP, Slooff TJJH, Timperley AJ. Impacted cancellous allografts and cement for revision total hip arthroplasty. *J Bone Joint Surg Br*1993;75:14-21.
19. Oakes DA, Cabanela ME. Impaction bone grafting for revision hip arthroplasty: biology and clinical applications. *J Am Acad Orthop Surg* 2006;14:620-8.
20. Van der Donk S, Buma P, Slooff TJ, Gardeniers JW, Schreurs BW. Incorporation of morselized bone grafts: a study of 24 acetabular biopsy specimens. *Clin Orthop Relat Res* 2002;396:131-41.
21. Schreurs BW. Busch V J. Welten ML. Verdonschot N. Slooff TJ, Gardeniers JW. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004;86:2385-92.
22. Schreurs BW, Gardeniers JW, Slooff TJ. Acetabular reconstruction with bone impaction grafting: 20 years of experience. *Instructional Course Lect* 2001;50:221-8.
23. Schreurs BW, Arts JJ, Verdonschot N, Buma P, Slooff TJ, Gardeniers JW. Femoral component revision with use of impaction bone-grafting and a cemented polished stem. *J Bone Joint Surg Am* 2005;87:2499-507.
24. Schreurs BW, Arts JJ, Verdonschot N, Buma P, Slooff TJ, Gardeniers JW. Femoral component revision with use of impaction bone-grafting and a cemented polished stem. Surgical technique. *J Bone Joint Surg Am* 2006;88 Suppl 1 Pt 2:259-74.
25. Slooff TJ, Buma P, Schreurs BW, Schimmel JW, Huiskes R, Gardeniers JW. Acetabular and femoral reconstruction with impacted graft and cement. *Clin Orthop Relat Res* 1996;324:108-15.
26. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG, Steinberg ME, Stulberg SD, Wedge JH. Classification and management of acetabular abnormalities in total hip arthroplasty. *Clin Orthop Relat Res* 1989;243:126-37.
27. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am*1969;51:737-55.
28. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br* 1996;78:185-90.
29. Brokelman RB, van Loon CJ, Rijnberg WJ. Patient versus surgeon satisfaction after total hip arthroplasty. *J Bone Joint Surg Br* 2003;85:495-8.

30. Bullens PH, van Loon CJ, de Waal Malefijt MC, Laan RF, Veth RP. Patient satisfaction after total knee arthroplasty: a comparison between subjective and objective outcome assessments. *J Arthroplasty* 2001;16:740-7.
31. De Nies F, Fidler MW. Visual analog scale for the assessment of total hip arthroplasty. *J Arthroplasty* 1997;12:416-9.
32. Dolan P, Sutton M. Mapping visual analogue scale health state valuations onto standard gamble and time trade-off values. *Soc Sci Med* 1997;44:1519-30.
33. Robinson A, Dolan P, Williams A. Valuing health status using VAS and TTO: what lies behind the numbers? *Soc Sci Med* 1997;45:1289-97.
34. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976;121:20-32.
35. Goodman SB, Adler SJ, Fyhrie DP, Schurman DJ. The acetabular teardrop and its relevance to acetabular migration. *Clin Orthop Relat Res* 1988;236:199-204.
36. Salvati EA, Im VC, Aglietti P, Wilson PD Jr. Radiology of total hip replacements. *Clin Orthop Related Res* 1976;121:74-82.
37. Dorr LD, Wan Z. Comparative results of a distal modular sleeve, circumferential coating, and stiffness relief using the Anatomic Porous Replacement II. *J Arthroplasty* 1996;11:419-28.
38. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;141:17-27.
39. Harris WH, McCarthy JC Jr, O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg Am* 1982;64:1063-7.
40. Loudon JR. Charnley J. Subsidence of the femoral prosthesis in total hip replacement in relation to the design of the stem. *J Bone Joint Surg Br* 1980;62:450-3.
41. Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr. Ectopic ossification following total hip replacement. Incidence and a method of classification. *J Bone Joint Surg Am* 1973;55:1629-32.
42. Thorey F, Lerch M, Kiel H, von Lewinski G, Stukenborg-Colsman C, Windhagen H. The uncemented primary Bicontact stem in revision total hip arthroplasty in young patients. *Z Orthop Unfall* 2007;145 Suppl 1:S40-3.
43. Stromberg CN, Herberts P. Cemented revision total hip arthroplasties in patients younger than 55 years old. A multicenter evaluation of second-generation cementing technique. *J Arthroplasty* 1996;11:489-99.
44. Raut VV, Siney PD, Wroblewski BM. Revision of the acetabular component of a total hip arthroplasty with cement in young patients without rheumatoid arthritis. *J Bone Joint Surg Am* 1996;78:1853-6.
45. Smith SE, Estok DM, Harris WH. 20-year experience with cemented primary and conversion total hip arthroplasty using so-called second-generation cementing techniques in patients aged 50 years or younger. *J Arthroplasty* 2000;15:263-73.


10

Chapter 10

Summary and general discussion

D.C.J. de Kam

Summary
In the Netherlands, almost 21.000 total hip arthroplasties are implanted every year. The total hip arthroplasty is one of the most successful medical interventions of the last decades. For over 50 years, total hip arthroplasties have been implanted in patients and because of the good results over the last 3 decades, this operation is more frequently performed in young patients (under 50 years). The results of total hip arthroplasties in older patients are in general very good, but the results in young patients are more variable. Different factors are responsible for this unfavourable outcome.

Young patients are more active and they engage in higher and longer activity levels. A higher activity level is associated with higher revision rates. This could be attributed to the higher wear rates of the polyethylene cups or inserts (PE wear). Young patients have increased demands and they put higher loads on the prosthesis. They participate in more extensive and heavy activities.

Young patients commonly have secondary osteoarthritis and acetabular bone deficiencies due to underlying diseases like developmental dysplasia of the hips or rheumatoid arthritis. In contrast to the older population, these defects are more common in young patients. In our view, before implantation of the acetabular component these bone defects must first be reconstructed. At the Radboud University Nijmegen Medical Centre these defects are always reconstructed with metal meshes, impacted bone grafts and a cemented full polyethylene cup. This technique has been designed, developed, refined, used and studied in our Orthopaedic Centre since 1979. The results of the bone impaction grafting technique are excellent in older patients.

The objective of this thesis is to evaluate the results of cemented primary total hip arthroplasties in young patients under 40 and 50 years of age and the results of cemented revision total hip arthroplasties in patients under 60. A second objective is to evaluate the use of acetabular reconstructions with impacted bone grafts within these patient populations in both primary and revision THA.

In **Chapter 2** the theoretical basis of this thesis is described. Using a literature review, all long-term studies concerning THA results are evaluated. Only studies with a mean follow-up of more than 10 years were selected. Our search query resulted in 2999 hits. After screening these hits, only 109 articles about total hip arthroplasties in patients under the age of 50 fulfilled our criteria in general. However, only 37 out of 109 articles (34%) had a mean follow-up of more than 10 years and were selected. The results of these studies were compared with the NICE-criteria. The NICE study group defines that a prosthesis should have a survival rate of more than 90% after 10 years with endpoint revision for any reason. Subsequently, only 15 out of the 37 studies complied with the NICE-criteria. 13 of these studies describe the results of cemented implants, 1 of uncemented implants, and in 1 study multiple techniques were used.

In a comparison of all studies with a mean follow-up longer than 10 years, this review shows that the cemented prostheses have significant better survival rate than uncemented implants in patients under 50 years.

The Exeter™ (Stryker-Howmedica, Newbury, UK) prosthesis is an implant that is being used worldwide in large numbers. The Exeter prosthesis was introduced in our clinic in 1991 and has been our standard prosthesis in primary total hip arthroplasty at the Radboud University Nijmegen Medical Centre since 1998. Analysis of the results of the Exeter stem in patients under the age of 40 is presented in **Chapter 3**.

In this study 104 Exeter stems in 78 patients were evaluated. The mean age at surgery was 31 years (range 16-39 years). After a mean follow-up of 6.2 years (range 2-13 years), 3 femoral stems (3%) were revised. All revisions were performed because of infection and septic loosening. After 7 years the survival rate of all femoral implants was 96% (95%CI 87-99%) with endpoint revision for any reason. No aseptic loosenings were seen, given a survival of 100% after 7 years with endpoint revision because of aseptic loosening.

The cemented Exeter stem gives excellent mid-term results in very young patients under the age of 40. These results compare nicely with the long term results of the Exeter implant published by the Exeter hospital in the UK, the originators of the implant.

Chapter 4 describes the results of conventional cemented polyethylene cups. In general literature, higher revision rates are found for the acetabular cup than for the femoral stem. The acetabular cup is the weakest link of a total hip arthroplasty. In our study, 175 cups in 130 patients under the age of 40 were evaluated. The mean age was 31 years (range 16-39) and the mean follow-up was 8.1 years (range 2.0-18.5 years). In this study group a total of 84 hips (48%) had an acetabular defect which needed reconstruction with bone impaction grafting.

In 21 cases (12%) a cup revision was needed. 8 cups were revised because of infection, 2 because of recurrent dislocations, 1 because of a traumatic loosening, and 10 due to aseptic loosening. Four out of 10 revised cups because of aseptic loosening have had an acetabular reconstruction with impacted bone grafts. These cups implanted in more difficult and defected acetabuli were revised after a mean follow-up of 11.7 years. The remaining 6 cups without acetabular reconstruction, plain primary cups, were revised after a mean of 4.0 years. The difference is statistically significant (p=0.032). After 10 years the survival rate of all cups was 85% (95%CI 78-92%) with endpoint revision for any reason. With aseptic loosening as endpoint, 90% (95%CI 81-99%) of the cups without a reconstruction was revision free after 10 years. Of the cups with an acetabular reconstruction with impacted bone grafts, 95% (95%CI 89-100%) was revisions free after 10 years. This was not a statistically significant difference (p=0.73).

Cemented polyethylene cups in patients under the age of 40 show good results on the long-term. The cups with an acetabular reconstruction with impacted bone grafts showed a clear positive tendency in longer survival compared to the cups without a reconstruction. This could be the result of lower activity levels of the patients which needed a reconstruction. However, the wear of the cup, which is related to activity, as well as the Harris Hip score was the same for the cups with or without an acetabular reconstruction. The philosophy is that the reconstruction using bone impaction grafting creates a better and stronger trabecular interface between the bone, graft, cement and cup.

The long-term results of both the cup and stem in patients under 40 years in our study are promising (**Chapter 5**). Analysis of a group of 130 patients under 40 years (175 hips) shows that was 83% (95%CI 76-90%) of all total hip arthroplasties survived at 10-year with endpoint revision for all reasons. Survival with endpoint revision for aseptic loosening was even 92% (95%CI 86-98%). After a mean follow-up of 8.1 years (range 2.0-18.5 years), 24 of the 175 hips were revised. Aseptic loosening was the most frequent indication for revision (11 hips). There were also revisions because of septic loosening (8), recurrent dislocations (4), and traumatic loosening (1). Additionally, 8 peroperative complications were seen. Postoperative there were 35 complications of which 7 needed a surgical intervention.

Replacement of the hip joint in patients under 40 years with a cemented total hip arthroplasty gives acceptable long term results. If we compare these results to the results in published studies, the results of uncemented total hip prosthesis are inferior to the published results of cemented prostheses in patients under 40 years of age.

In **Chapter 6** all cemented total hip prostheses in all patients aged between 40 and 50 years at the time of the operation, were examined. 140 consecutive patients with in total 168 total hip prostheses were included. Acetabular reconstruction using bone impaction grafting was necessary in 70 hips (42%). The average follow-up was 10 (range 2-19) years. During the follow-up 29 hips (17%) were revised.

The clinical results using questionnaires showed statistically significant improvement after the surgery. Kaplan-Meier survival analysis showed a survival rate of 88% (95%CI

82-94%) after 10 years with endpoint revision for any reason. Survival with endpoint revision for aseptic loosening was 94% (95%CI 90-99%) after 10 years.

This study shows that the chances of survival of cemented prostheses in patients aged between 40 and 50 years are high and comparable to the results achieved with cemented total hip arthroplasties in the elderly population. Reconstructions of acetabular bone defects with impacted morselized bone grafts in this population give promising results and are equal to the results of total hip prostheses without acetabular reconstructions, keeping in mind that the reconstructed cups are the more difficult hips.

Because of the promising results of the total hip arthroplasties reconstructed with impacted bone grafts in young patients (Chapters 4, 5 and 6), in **Chapter 7** all total hip arthroplasties reconstructed with impacted bone grafts in all patients that were under the age of 50 at the time of surgery, and operated at our department since the development of this technology in 1979 were evaluated. Since 1979 177 hips in 150 patients have been reconstructed with impacted bone grafts. The average age was 38 years (range 16-49 years) and the average follow-up was 10.3 (range 2-28.3) years. 34 hips (19%) had a type 1 segmental defect, 97 (55%) had a type 2 cavitary defect, 45 (25%) had a type 3 combined defect, and 1 (0.6%) patient had a bony ankylosis according to the classification of the AAOS for bone defects.

Of the 177 hips 28 were revised. This leads to a survival rate of 91% after 10 years and 78% after 15 years with endpoint revision for all reasons. The survival rate with endpoint aseptic loosening was 96% for the cup and 97% for the stem after 10 years. Clinical outcome measured with clinical questionnaires increased significantly postoperative.

In conclusion, total hip arthroplasties reconstructed with impacted bone grafts show good results and meet the NICE-criteria (a survival of >90% after an average follow-up of 10 years with endpoint revision for any reason).

In **Chapter 8**, the concept of revisability is introduced using the results of 343 cemented total hip arthroplasties in 270 patients aged under 50 years. Not only were the results of the primary total hip prosthesis evaluated, but we evaluated also to the results of the 53 revisions within the same population. The average age at the time of the primary operation was 38 (range 16-49) years. The average follow-up was 8.9 years (range 2.0-19.3 years) for the primary hip prostheses and 4.2 (range 0.1-14.8) years for the revision total hip arthroplasties. Acetabular reconstruction with impacted bone grafts was primarily performed in 155 hips (45%). The most common diagnoses in this age group were: congenital hip dysplasia, rheumatoid arthritis, and corticosteroids induced femoral head necrosis.

53 of the 343 primary total hip prostheses were revised. In 2 cases with septic loosening, it was decided that no new hip prosthesis should be implanted but a permanent Girdlestone situation was created. A re-revision was necessary in 3 of the 51 revised hips (6%) because of aseptic loosening (n=1) and septic loosening (n=2).
In the group of primary total hip prostheses the survival rate was 86% with endpoint revision for any reason after 10 years. The survival with endpoint aseptic loosening was 100% and 93% after 10 years for the stem and cup respectively. Survival of the revisions was 91% after 5 years with endpoint re-revision because of any reason and 100% with endpoint re-revision for aseptic loosening after 5 years. The outcome of clinical questionnaires improved significantly postoperative, both in the primary and revision total hip arthroplasty patients.

Cemented implants in young patients provide satisfactory results in both primary and revision arthroplasties with a good survival rate and good clinical outcome. The use of impacted bone grafts for the reconstruction of bone defects enhances the revisability of a THA.

Chapter 9 describes the results of cemented revision hip arthroplasties in patients under the age of 60. Not only the results of a primary hip prosthesis should be good, but also the results of the following revision. All patients who have undergone a revision between 1992 and 2005 and under the age of 60 were evaluated. A total of 146 revisions in 129 patients were included. There were 124 cup and 106 steel revisions. All bone defects were reconstructed using impacted morselized bone grafts. The average age was 47 years and the average follow-up was 7.6 (range 2.0 16.7) years.

During the follow-up in 19% (28 hips) a re-revision was necessary. Reasons for re-revision were: aseptic loosening (13), septic loosening (10), recurrent dislocations (2), traumatic loosening (2), and abductor contractracture (1). All bone defects were reconstructed with impacted bone grafts. Repeat revision of 7 of the 146 hips (5%) was not possible due to recurrent and permanent infection and ended in a permanent Girdlestone situation. The 10-year survival rate was 78% with endpoint re-revision for any reason and 87% with endpoint re-revision for aseptic loosening. No significant differences in survival were seen between the different indications for revision.

The survival of cemented revisions in patients under 60 shows fairly good results. Compared to the published literature, the results are at least similar or even better. Reconstruction of bone defects with impacted bone grafts, both acetabular and femoral, leads to acceptable results and improves the revisability of the revision because of restoration of the bone defects in a biological manner and at the next rerevision bone stock is generally preserved.

Conclusion

This thesis describes the results of cemented total hip arthroplasties in young patients. In the different chapters the results of cemented total hip prostheses in patients younger than 50 years in primary hip prostheses or 60 years at the time of the surgery in revision hip arthroplasty, are presented.

The results of the studied populations are similar to the results of cemented total hip arthroplasties in the literature. The results of cemented total hip arthroplasties are better than the published results of uncemented total hip prostheses in young patients. Based on this information, it could be stated that in young patients a cemented total hip prostheses is still preferred over an uncemented implant. This is definitely in contrast to what most leading expert surgeons and the orthopaedic industry claims. The Scandinavian Hip Arthroplasty Registers show that the use of uncemented components increases and the use of cemented components decreases in young patients and this in contrast to the shown long term results. In some countries even cemented implants were and are never used in this challenging population. In this thesis, it is stated that the results of the 'old-fashioned' well cemented hip arthroplasty are favorable and attractive. In addition, the outcome of revisions of these cemented hips also leads to acceptable results.

Multiple studies show that the acetabular cups reconstructed with impacted bone grafts have a positive tendency in better survival rates than the cups without an acetabular reconstruction. This difference cannot be explained by differences in activity levels, but it is probably related to the intrinsic characteristics of this reconstruction technique. Further research into the characteristics of the created interface between bone, grafts, cement, and cup is necessary. Pitfalls of this technique are that it is a difficult reconstruction method, it is relatively more time consuming, and the postoperative mobilisation is often delayed.

The conclusion of this study is that cemented implants definitely have good results in young patients, in both the past and present with the implants used nowadays. One could consider if not every total hip arthroplasty in younger patients should be reconstructed with impacted bone grafting to create this improved trabecular interface between host bone, impacted graft, cement and cup. This technique provides a better survival of the acetabular cup, which is normally the weakest link of a total hip arthroplasty.

With this thesis the challenge has not yet been completed. It only describes a small proportion of all the factors related to total hip arthroplasty, different techniques, and survival. A few suggestions for further research are:

- The real long-term survival (>20yrs) of THA in young patients.
- The level of activity in young total hip arthroplasty patients.
- The long-term survival of the acetabular cup with newer bearing materials and the consequences of the use of these materials in wear rates.
- The cytological, histological and biomechanical aspects of the graft, host bone, cement, and cup interface in bone impaction grafting.
- The long-term survival of the new generation uncemented implants in young patients.

Chapter 11

Samenvatting en algemene discussie

D.C.J. de Kam

Samenvatting
In Nederland worden jaarlijks bijna 21.000 totale heupprothesen geplaatst. De totale heupprothese is één van de meest succesvolle medische interventies van de afgelopen decennia. Al meer dan 50 jaar worden totale heupprothesen bij patiënten geïmplanteerd, waarbij de laatste 3 decennia deze operatie ook steeds meer bij jonge patiënten (<50 jaar) wordt uitgevoerd. De resultaten van een totale heupprothese bij oudere patiënten zijn doorgaands zeer goed, maar de lange termijn resultaten bij de jongere patiënten populatie zijn zeer wisselend. Hiervoor zijn verschillende oorzaken aan te wijzen. Allereerst neemt men aan dat jonge patiënten actiever zijn. Een hoger activiteitsniveau is gecorreleerd aan een hoger revisie percentage. Dit zou verklaard kunnen worden door meer slijtage van het polyethyleen waarvan de cup of insert doorgaans gemaakt is (PE wear). Jonge patiënten belasten hun prothese zwaarder. Ze nemen deel aan zwaardere en inspannender activiteiten.

Ook hebben jonge patiënten vaak een onderliggende diagnose welke gepaard gaat met forse destructie van het acetabulum, bijvoorbeeld congenitale heupdysplasie of reumatoïde artritis. In tegenstelling tot de oudere patiëntengroep zijn grote acetabulaire defecten eerder regelmaat dan uitzondering. Deze defecten moeten eerst gereconstrueerd worden voordat er een acetabulaire cup geplaatst kan worden. In het UMC St Radboud worden deze defecten altijd gereconstrueerd met metaal gazen of netjes, geïmpacteerde botsnippers en een gecementeerde polyethyleen cup. Deze techniek wordt al vanaf 1979 gebruikt en is sindsdien verder ontwikkeld. De resultaten van deze techniek zijn zeer goed, zowel bij de oudere als bij de jongere patiënt.

Doel van dit proefschrift is het evalueren van de resultaten van gecementeerde primaire totale heupprothesen bij patiënten onder de 50 jaar en van revisie totale heupprothesen bij patiënten onder de 60 jaar. Tevens wordt het gebruik geëvalueerd van acetabulaire reconstructies met geïmpacteerde botsnippers in deze patiënten populaties.

In **Hoofdstuk 2** wordt de theoretische basis voor dit proefschrift gelegd. Met behulp van een literatuur review is gekeken wat de gepubliceerde resultaten waren van lange termijn studies. Als selectie criteria is gekozen om alleen studies met een gemiddelde follow-up van 10 jaar of meer mee te nemen. Met behulp van de onderzoeksvraag kregen we 2999 hits, na selectie bleven er 109 artikelen over die over totale heupprothesen bij patiënten onder de 50 jaar gingen. Slechts 37 van de 109 (34%) studies hadden een gemiddelde follow-up van 10 jaar of meer. De resultaten van deze studies werden naast de NICE-criteria gehouden. De NICE werkgroep stelt dat een goede prothese een overleving van meer dan 90% zou moeten hebben na gemiddeld 10 jaar met eindpunt revisie voor alle redenen. Van de 37 studies voldeden er maar 15 aan de NICE-criteria, hiervan waren er 13 over gecementeerde prothesen, 1 over ongecementeerde prothesen en in 1 studie werden meerdere technieken gebruikt.

Bij een vergelijking van de resultaten van alle studies met een gemiddelde follow-up van minimaal 10 jaar, bleek dat de gecementeerde prothesen een statistisch significant betere overleving hadden dan ongecementeerde prothesen bij patiënten onder de 50 jaar.

De Exeter™ (Stryker-Howmedica, Newburry, Groot-Brittannië) prothese is een implantaat dat wereldwijd steeds vaker wordt gebruikt. Deze prothese werd in 1991 geïntroduceerd in onze kliniek en is vanaf 1998 de standaard prothese die gebruikt wordt bij totale heupvervanging in het UMC St Radboud. Analyse van de resultaten van de Exeter steel bij patiënten onder de 40 jaar werd besproken in **Hoofdstuk 3**.

In deze studie werden 104 Exeter stelen in 78 patiënten onderzocht. De gemiddelde leeftijd in deze groep was 31 jaar (spreiding 16-39 jaar). Na een gemiddelde follow-up van 6.2 jaar (spreiding 2-13 jaar) waren 3 femorale stelen (3%) gereviseerd. Allen waren gereviseerd wegens septische loslating. Na 7 jaar was de overleving van alle prothesen met als eindpunt revisie voor welke reden dan ook 96% (95%B.I. 87-99%). Er

waren geen aseptische steel loslatingen, hierdoor was de overleving met eindpunt aseptische loslating van de steel 100% na 7 jaar.

De gecementeerde Exeter steel laat zeer goede middellange termijn resultaten zien bij jonge patiënten onder de 40 jaar.

Hoofdstuk 4 beschrijft de resultaten van conventionele gecementeerde polyethyleen cups. In de literatuur blijkt dat de cup een hogere revisie percentage heeft dan de steel. Dit maakt de cup tot de zwakste schakel van een totale heupprothese. Er werden 175 cups in 130 patiënten onder de 40 jaar geëvalueerd. De gemiddelde leeftijd was 31 jaar (spreiding 16-39) en de gemiddelde follow-up was 8.1 jaar (spreiding 2.0-18.5 jaar). In totaal was er in 84 heupen (48%) sprake van een dusdanig acetabulair defect dat reconstructie met geïmpacteerde botsnippers noodzakelijk was.

In 21 gevallen (12%) vond er een revisie van de cup plaats. Er werden 8 cups gereviseerd wegens infectie, 2 wegens recidiverende luxaties, 1 wegens een traumatische loslating en 10 wegens aseptische loslating. Van de 10 gereviseerde cups wegens aseptische loslating waren er 4 gereconstrueerd met geïmpacteerde botsnippers. Deze cups werden na gemiddeld 11.7 jaar gereviseerd. De 6 gereviseerde cups zonder reconstructie waren na gemiddeld 4.0 jaar gereviseerd. Dit verschil is significant ($p=0.032$). Na 10 jaar was de overleving van alle cups 85% (95%B.I. 78-92%) met eindpunt revisie voor welke reden dan ook. Kijkend naar de aseptische loslatingen was 90% (95%B.I 81-99%) van de cups zonder reconstructie revisie vrij na 10 jaar. Van de cups met reconstructie met geïmpacteerde botsnippers was 95% (95%B.I 89-100%) revisie vrij na 10 jaar. Dit verschil was echter niet significant ($p=0.73$).

Gecementeerde polyethyleen cups in patiënten onder de 40 jaar laten een goede overleving zien op de lange termijn. De cups met een reconstructie met geïmpacteerde botsnippers hadden een positieve trend in betere overleving ten opzichte van de cups zonder reconstructie. Mogelijk dat dit komt door een lager activiteitsniveau van de patiënten met een reconstructie, echter de slijtage van de cup welke afhankelijk is van activiteit was gelijk voor de cups met en zonder acetabulaire reconstructie. Waarschijnlijk zorgt de reconstructie met geïmpacteerde botsnippers voor een betere interface tussen bot, graft, cement en cup.

De lange termijn resultaten van zowel de cup als steel in patiënten onder de 40 jaar zijn veelbelovend (**Hoofdstuk 5**). Na analyse van een groep van 130 patiënten onder de 40 jaar (175 heupen) was de 10-jaars overleving van de totale heupprothesen 83% (95%B.I. 76-90%) met eindpunt revisie voor alle redenen. Aseptische overleving was zelfs 92% (95%B.I. 86-98%).

Na een gemiddelde follow-up van 8.1 jaar (uitersten 2.0-18.5 jaar) werden 24 heupen gereviseerd. Aseptische loslating was de meest voorkomende indicatie voor revisie (11 heupen). Er werden tevens heupen gereviseerd vanwege septische loslating (8), recidiverende luxaties (4) en traumatische loslating (1). Verder werden er 8 peroperatieve complicaties gezien. Postoperatief waren er 35 complicaties waar er bij 7 een chirurgische interventie noodzakelijk was.

Vervanging van het heupgewricht bij patiënten onder de 40 jaar door een gecementeerde totale heupprothese laat goede langetermijn resultaten zien. Als we deze resultaten vergelijken met de resultaten gepubliceerd in de literatuur blijkt dat de resultaten van ongecementeerde totale heupprothese niet zo goed zijn als de gepubliceerde resultaten van gecementeerde prothesen in patiënten onder de 40 jaar.

Om de studie populatie uit te breiden werden in **Hoofdstuk 6** alle gecementeerde totale heupprothesen bij patiënten die ten tijde van de operatie tussen de 40 en 50 jaar waren onderzocht. Er werden 140 opeenvolgende patiënten geïncludeerd met in totaal 168 totale heupprothesen. Acetabulaire reconstructie werden weer uitgevoerd met behulp van geïmpacteerde botsnippers en was in 70 heupen noodzakelijk. De gemiddelde follow-up

was 10 (spreiding 2-19) jaar. Tijdens de follow-up werden 29 heupen (17%) gereviseerd. Alle patiënten werden zowel klinisch als radiologisch vervolgd.

De uitkomsten van klinische vragenlijsten verbeterden statistisch significant na de operatie. Kaplan-Meier overleving analyse liet een overleving zien van 88% (95%B.I. 82-94%) na 10 jaar met eindpunt revisie voor alle redenen. Overleving met eindpunt revisie wegens aseptische loslating was 94% (95%B.I. 90-99%) na 10 jaar.

Uit dit onderzoek blijkt dat de overleving van gecementeerde prothesen bij patiënten tussen de 40 en 50 jaar goed zijn en zelfs vergelijkbaar zijn met de resultaten behaald met gecementeerde totale heupprothesen bij de normale, oudere populatie. Reconstructies van acetabulaire defecten met geïmpacteerde botsnippers in deze populatie laten veelbelovende resultaten zien en zijn gelijk aan de uitkomsten van totale heupprothesen zonder reconstructies, terwijl dit doorgaands toch de moeilijkere heupen zijn.

Aangezien de resultaten in de voorgaande studies van de totale heupprothesen met een acetabulaire reconstructie met geïmpacteerde botsnippers veelbelovend waren, hebben we in **Hoofdstuk 7** alle heupen onder de 50 jaar nagekeken die sinds de ontwikkeling van deze techniek zijn geïmplanteerd. Hiervoor werden alle heupprothesen bij patiënten onder de 50 jaar zijn geïmplanteerd sinds 1979 geëvalueerd. Sinds 1979 zijn 177 heupen in 150 patiënten gereconstrueerd met geïmpacteerde botsnippers. De gemiddelde leeftijd was 38 jaar (16-49) en de gemiddelde follow-up bedroeg 10.3 (spreiding 2-28.3) jaar. 34 heupen (19%) hadden een type 1 segmentaal defect, 97 (55%) een type 2 cavitair defect, 45 (25%) een type 3 gecombineerd defect en 1 (0.6%) patiënt had een benige ankylosis volgens de classificatie van de AAOS voor botdefecten.

Van de 177 heupen werden 28 heupen gereviseerd. Dit gaf een overleving van 91% na 10 jaar en 78% na 15 jaar met eindpunt revisie voor alle redenen. Overleving met eindpunt aseptische loslating was 96% voor de cup en 97% voor de steel na 10 jaar. Klinische uitkomst gemeten met vragenlijsten nam postoperatief ook significant toe.

Concluderend laten totale heupprothesen gereconstrueerd met geïmpacteerde botsnippers goede resultaten zien die zelf de NICE-criteria halen (overleving van >90% na gemiddeld 10 jaar).

In **Hoofdstuk 8** werd met behulp van de resultaten van 343 gecementeerde totale heupprothesen bij 270 patiënten onder de 50 jaar het begrip reviseerbaarheid gedefinieerd. Daarvoor werd niet alleen gekeken naar de resultaten van de primaire totale heupprothese, maar ook naar de resultaten van de 53 uitgevoerde revisies binnen dezelfde populatie. De gemiddelde leeftijd ten tijde van de operatie was 38 (spreiding 16-49 jaar). De follow-up bedroeg gemiddeld 8.9 jaar (spreiding 2.0-19.3 jaar) voor de primaire heupprothesen en 4.2 (spreiding 0.1-14.8) jaar voor de revisie heupprothesen. Acetabulaire reconstructie met geïmpacteerde botsnippers was primair nodig in 155 heupen (45%). De meest voorkomende diagnosen in deze leeftijdsgroep waren: congenitale heupdysplasie, reumatoïde artritis en corticosteroïden geïnduceerde kopnecrose. 53 van de 343 primaire totale heupprothesen werden gereviseerd. In 2 gevallen werd besloten om geen nieuwe heupprothese te plaatsen en een permanente Girdlestone situatie te creëren. Een re-revisie was noodzakelijk in 3 van de 51 revisies (6%) wegens aseptisch loslating (n=1) en septische loslating (n=2).

Kijkend naar de primaire totale heupprothesen was met eindpunt revisie voor alle redenen na 10 jaar 86% revisie vrij. De overleving met eindpunt aseptische loslating was 100% en 93% na 10 jaar voor de steel en cup. Overleving van de revisies was 91% na 5 jaar met eindpunt re-revisie wegens alle redenen en 100% met eindpunt revisie wegens aseptische loslating na 5 jaar.

Zowel na de primaire als na de revisie heupprothese was een significante toename te zien van de uitkomsten van klinische vragenlijsten.

Gecementeerde implantaten in jonge patiënten laten bevredigende resultaten zien zowel in primaire als in revisie prothesen met goede survival en klinische uitkomsten. Om

de reviseerbaarheid te definiëren is geopperd om een criterium te stellen met een overleving van >90% voor de primaire en >85% voor de revisie prothese, samen met een klinische waardering van minimaal 75% na primaire en revisie totale heupprothese.

Hoofdstuk 9 gaat over de resultaten van gecementeerde revisie heupprothesen bij patiënten onder de 60 jaar. Niet alleen de resultaten van een primaire heupprothese moet goed zijn, maar ook de resultaten van de daaropvolgende revisie of re-revisie. Alle patiënten die een revisie ondergingen tussen 1992 en 2005 en die jonger waren dan 60 jaar werden geëvalueerd. In totaal werden 146 revisies bij 129 patiënten verricht. Hierbij werden 124 cup en 106 steel revisies uitgevoerd. Alle botdefecten werden gereconstrueerd met behulp van geïmpacteerde botsnippers. De gemiddelde leeftijd bij revisie was 47 jaar en de follow-up bedroeg gemiddeld 7.6 (spreiding 2.0-16.7) jaar.

Tijdens de follow-up was in 19% (28 heupen) een re-revisie noodzakelijk. Redenen voor re-revisie waren: aseptische loslating (13), septische loslating (10), recidiverende luxaties (2), traumatische loslating (2) en abductor contractuur (1). Weer werden eventuele botdefecten met geïmpacteerde botsnippers gereconstrueerd. 7 van de 146 heupen (5%) eindigden in een permanente Girdlestone.

De 10-jaars overleving was 78% met eindpunt revisie voor elke reden en 87% met eindpunt revisie voor aseptische loslating. Geen statistische significante verschillen in overleving waren zichtbaar tussen de verschillende oorzaken voor revisie.

De overleving van gecementeerde revisies bij patiënten onder de 60 jaar is redelijk goed. In vergelijking met de literatuur zijn de behaalde resultaten vergelijkbaar of vaak zelfs beter. Reconstructie van botdefecten, zowel acetabulair als femoraal, laten goede resultaten zien en verbeteren de reviseerbaarheid van de revisie omdat bot defecten biologisch worden aangevuld.

Conclusie

Dit proefschrift beschrijft de resultaten van gecementeerd prothesen bij jonge patiënten. In de verschillende hoofdstukken worden de resultaten onderzocht van gecementeerde totale heupprothesen die geplaatst werden bij patiënten die ten tijde van de operatie jonger waren dan 50 jaar bij primaire heupprothesen of 60 jaar bij revisies.

De resultaten van de onderzochte populaties zijn vergelijkbaar met de resultaten van gecementeerde totale heupprothesen in de literatuur. De resultaten van gecementeerde totale heupprothesen zijn beter dan de gepubliceerde resultaten van ongecementeerde totale heupprothesen bij jonge patiënten. Op basis van deze gegevens kan men stellen dat bij jonge patiënten de voorkeur uit gaat naar gecementeerde totale heupprothesen. Dit in tegenstelling tot wat vooraanstaande chirurgen of de orthopedische industrie beweren. Uit de Scandinavische implantaten registers blijkt dat het gebruik van ongecementeerde componenten toeneemt en het gebruik van gecementeerde componenten daalt bij jonge patiënten. In sommige landen worden überhaupt geen gecementeerde implantaten gebruikt bij deze uitdagende populatie. Uit dit proefschrift blijkt dat de resultaten van de 'ouderwetse' gecementeerde prothesen nog steeds aantrekkelijk zijn en dat ze zeer geschikt zijn om te gebruiken bij jonge patiënten omdat ze ook nog eens goed reviseerbaar zijn. Tevens zijn de resultaten van de revisie THA zeker acceptabel en concurrerend met andere methoden.

Tevens bleek uit meerdere studies dat de acetabulaire cups die een reconstructie met geïmpacteerde botsnippers ondergingen een trend in betere overleving hadden dan de cups zonder acetabulaire reconstructie. Dit verschil wordt niet verklaard door een verschil in activiteitniveau maar is waarschijnlijk gerelateerd aan de intrinsieke kenmerken van deze reconstructie techniek. Verder onderzoek naar de karakteristieken van de gevormde interface tussen bot, graft, cement en cup is noodzakelijk. Nadelen van deze techniek zijn dat de reconstructie methode moeilijk is, het is meer tijdsconsumerend en de postoperatieve mobilisatie is langzamer.

De conclusie van dit onderzoek is dat gecementeerde totale heupprothesen bij jonge patiënten zowel vroeger als tegenwoordig met de nieuwere implantaten goede resultaten

hebben. Tevens zou eigenlijk iedere totale heupprothese bij jongere patiënten geplaatst zou moeten worden met geïmpacteerde botsnippers. Deze techniek geeft een betere overleving van de acetabulaire cup, welke doorgaans de zwakste schakel is van een totale heupprothese.

Met dit proefschrift is de uitdaging nog niet voltooid. Het beschrijft enkel een klein gedeelte van alle aspecten van totale heupprothesen, verschillende technieken en overleving. Enkele suggesties voor verder onderzoek zijn:

- Resultaten van totale heupprothesen op de zeer lange termijn (>20jr)
- Activiteiten niveau van jonge patiënten met een totale heupprothese.
- Lange termijn resultaten van cups met nieuwere articulatie materialen (zoals keramiek, crosslinked PE) en de gevolgen van deze materialen of slijtage cijfers.
- Cytologische, histologische en biomechanische eigenschappen van de bot, graft, cement en cup interface in reconstructies met geïmpacteerde botsnippers.
- Lange termijn overleving van de nieuwere generatie ongecementeerde implantaten in jonge patiënten.

Dankwoord

'Even' het s-je van je naam afhalen, zo noemde ik mijn promotie onderzoek toen ik net begon. Nu, ruim 2 jaar en heel wat moeite verder, moet ik het begrip 'even' toch aanpassen. Een promotie is een hele onderneming en ik had het zeker niet kunnen volbrengen zonder de hulp en steun van een aantal mensen. Ondanks dat jouw naam op de voorkant van je boekje mag prijken doe je promoveren zeker niet alleen. Vele mensen hebben mij gesteund en geholpen om mijn promotie met succes af te ronden en mij voor te bereiden op de opleiding. Graag zou ik al deze mensen willen bedanken.

Wim, wat ben ik blij dat ik bij jou mijn onderzoek mocht doen. Tijdens mijn onderzoekstage van mijn geneeskunde opleiding vroeg je of ik wilde blijven om fulltime onderzoek te doen. Dit resulteerde in een zeer prettige en fijne samenwerking. We hebben heel wat uurtjes samen doorgebracht om alle studies door te nemen, röntgenfoto's te bekijken en alle stukken die ik had geschreven door te nemen. Tevens heb jij me helemaal wegwijs gemaakt in de wereld die heupprothesiologie heet. Volgens mij hebben al mijn manuscripten jou heel wat tijd en flessen wijn gekost. Je zult altijd wel een voorbeeld voor me blijven als een goede klinische arts en gepassioneerd onderzoeker.

Jean, met jouw ervaring en humor was het promoveren een stuk leuker. Je hebt altijd wel een mooie anekdote paraat en er was nooit een saai moment met jou in de buurt. Indien we iets te overleggen hadden had je altijd wel een vrij moment voor me en ik kon altijd bij je binnenlopen.

Professor Veth, het zal altijd wel professor voor me blijven. Bedankt voor alle overlegmomenten in de voorbereiding van mijn promotie en dat u mijn promotor wilt zijn. De overlegmomenten heb ik altijd ervaren als een moment van reflectie en voorbereiding. Ook werden alle adviezen uitgesproken om mijn carrière en promotie zo goed mogelijk te laten verlopen.

De manuscriptcommissie: hartelijk dank voor het beoordelen van mijn manuscript.

De jaren in de barak zouden zonder Joost, Martin en Jaap een stuk minder leuk zijn geweest. Met jullie hing er altijd wel een ontspannen academische sfeer in de bedompte barak lucht. We hebben heel wat afgelachen, gediscussieerd, ongein uitgehaald en gedart. Ik zal nooit de middag break dart wedstrijden vergeten en de (soms) hevige discussies over vele verschillende onderwerpen. Indien we onderzoekstechnisch met problemen of obstakels zaten konden we er samen wel vaak uitkomen. Ik kijk uit naar het moment dat we onze wall of fame vol krijgen.

Maarten, bedankt voor alle flexibiliteit en mogelijkheden voor en tijdens mijn klinische periode. Na deze periode heb ik ook je fijne samenwerking mogen ervaren tijdens enkele projecten.

Alle dames en heren van het assistentensecretariaat, het stafsecretariaat en de polikliniek orthopedie en heelkunde. Iedere keer wanneer ik met mijn verzoekjes aankwam werd alles tot in de puntjes geregeld. Dit kon variëren van het oproepen van patiënten tot het regelen van vergoedingen en aanvragen.

Al het personeel van de verpleegafdeling, zonder jullie zou ik zeker niet zo'n fijne tijd hebben gehad tijdens mijn klinische periode.

Tevens wil ik alle mensen op het orthopedisch en centraal OK-complex willen bedanken voor de fijne tijd als ik weer eens mocht genieten tijdens de operaties.

De medewerkers van het status- en röntgenarchief, bedankt voor alle steun en hulp bij het opzoeken van de patiënten statussen en oude röntgenfoto's van alle (ruim 500) patiënten.

Jan, als ik statistische ondersteuning nodig had kon ik altijd wel bij je terecht. Jij hebt me zeker meer wegwijs gemaakt in de wereld die statistiek heet.

Nienke, Moniek, Sofie, Paul, Gerdien, Katja, Linda, Dirk, Sander, Joost; ik vond het super om jullie te mogen begeleiden in het onderzoek tijdens jullie studentenperiode en onderzoekstages. Met enkele van jullie heb ik zelfs wat artikelen kunnen schrijven en opsturen. Veel succes in jullie toekomstige carrière.

Bram, Kim en Els; dank je voor alle etentjes en ontspanning. Het is fijn om jullie als vrienden te hebben. Ondanks het feit dat ieder nu meer zijn eigen weg aan het vinden is hoop ik dat de etentjes zullen blijven.

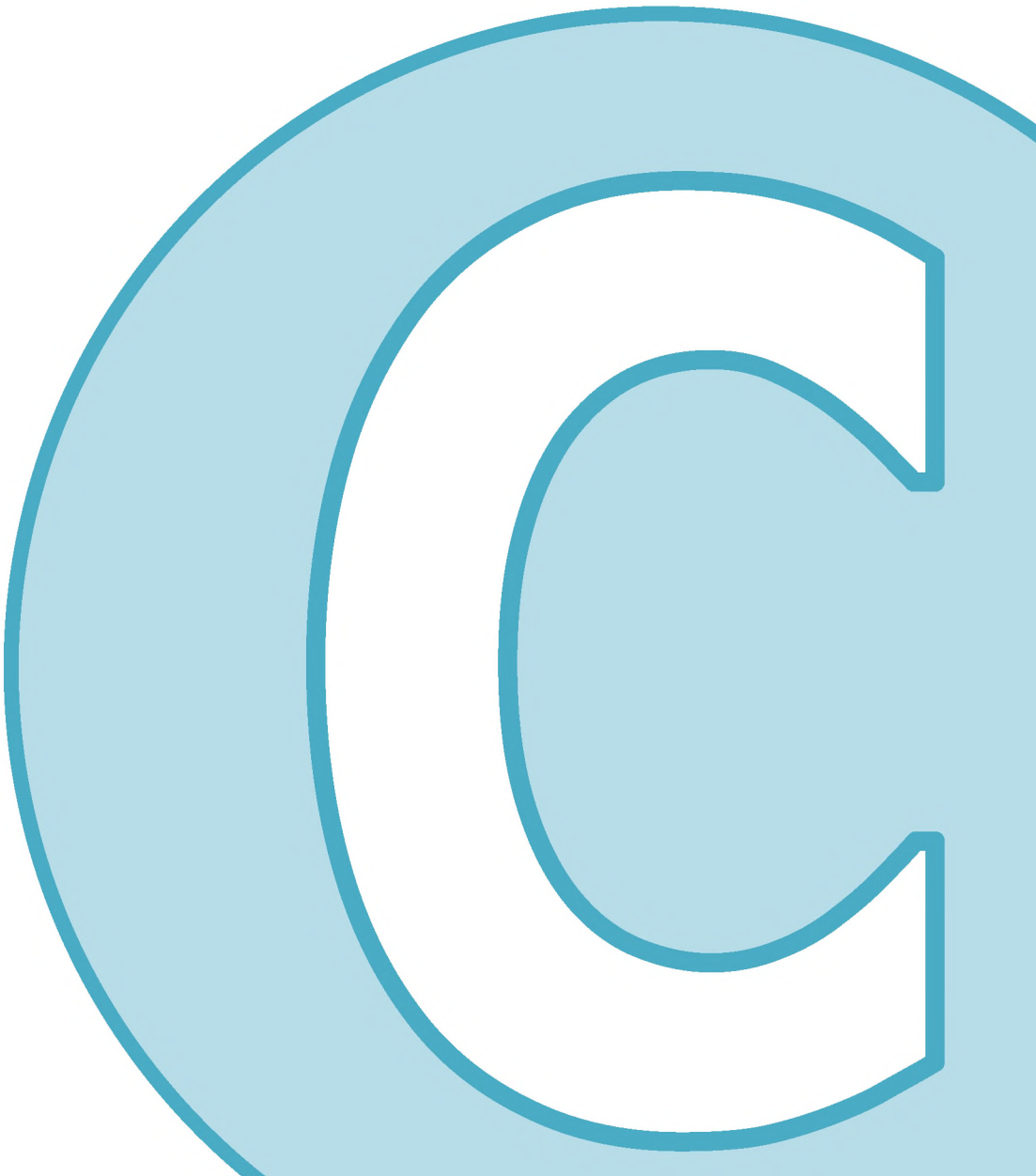
Beste Schoonouders, Marina, Stefanie en Antal & Carolien; dankzij jullie kon ik vaak nog even doorwerken terwijl jullie op mijn kostbare kroost pasten. Ook jullie interesse in mijn onderzoek stel ik zeer op prijs.

Ben, als mijn broertje kon ik altijd je hulp vragen als ik die nodig had. Samen met Lianne heb je ook diverse malen mijn kinderen kunnen bezighouden zodat ik kon werken of samen met Christa wat wel verdiende ontspanning kon genieten.

Pa en ma, nou dit is hij dan: mijn proefschrift. Dankzij jullie heb ik de kans gekregen om te worden wie ik ben. Jullie hebben me altijd vrij gelaten in alle keuzes van sport tot opleiding. Mijn dank is groot.

Christa, je staat hier als een van de laatste maar je verdient eigenlijk een hele speciale plaats in dit boekje. Zonder jou zou ikzelf niet compleet zijn. Je hebt me altijd ondersteund en je interesse getoond in alles wat ik deed. Dank je dat je me de vrijheid en kansen geeft om mijn dromen te verwezenlijken. Het heeft heel wat opofferingen van je gekost om mijn promotie en carrière op te bouwen. Tevens heb je me 2 kostbaarheden gegeven waar ik niet meer zonder kan: onze kinderen Nathan en Evelien.

Nathan en Evelien, ik zou jullie al kunnen bedanken voor alle slapeloze nachten die jullie mij en je moeder hebben bezorgd, maar deze vervallen in het niets als ik kijk naar alle vreugde, plezier en liefde die jullie me geven. Ik ben er trots op dat ik jullie vader mag zijn.



Curriculum Vitae and List of publications

List of publications

Articles:

De Kam DCJ, Klarenbeek RLWA, Gardeniers JWM, Veth RPH, Schreurs BW. The medium-term results of the cemented Exeter femoral component in patients under 40 years of age. Journal Bone and Joint Surgery Br. 2008;90(11):1417-21.

De Kam DCJ, Gardeniers JWM, Hendriks JCM, Veth RPH, Schreurs BW. Cemented polyethylene cups in patients under 40 years of age. Clinical Orthopaedics and Related Research. 2009;467(7):1753-64.

De Kam DCJ, Gardeniers JWM, Veth RPH, Schreurs BW. Een heupprothese met cement bij patiënten jonger dan 40 jaar en reconstructie van eventuele botdefecten met botsnippers. Nederlands Tijdschrift voor de Geneeskunde. 2009;154:A811.

De Kam DCJ, Busch VJJF, Veth RPH, Schreurs BW. Total hip arthroplasties in young patients under 50 years: limited evidence for current trends. Hip International [Accepted].

De Kam DCJ, Gardeniers JWM, Veth RPH, Schreurs BW. Good results with cemented primary total hip arthroplasty in patients between 40 and 50 years of age, 168 hips followed for 2-19 years. Acta orthopaedica. 2010;81(2):165-70.

De Kam DCJ, Busch VJJF, Gardeniers JWM, Slooff TJJH, Veth RPH, Schreurs BW. Thirty years experience with bone impaction grafting of acetabular deficiencies in combination with a total hip arthroplasty in young patients under fifty years. [Submitted].

De Kam DCJ, Schreurs BW, Gardeniers JWM, Veth RPH. The outcome of a large cohort of 343 consecutive hip arthroplasties in patients under 50 years and the outcome of their revisions. [Submitted].

De Kam DCJ, Van Heumen MRJ, Gardeniers JWM, Veth RPH, Schreurs BW. Cemented revision hip arthroplasty in patients younger than 60 years. [Submitted].

Egmond N, **De Kam DCJ**, Gardeniers JWM, Schreurs BW. Revisions of extensive Paprosky type 2B-3B acetabular defects with bone impaction grafting and a cemented cup. Clinical Orthopaedics and Related Research. 2011;469(2):562-73.

Konijn BM, **De Kam DCJ**, Dekker HM, Brink M, Deunk J, Hosman AJF. Occipital condyle fractures: clinical relevant or not? [Submitted].

Letters:

BW Schreurs, **De Kam DCJ**. Letter with comment on: Primary Total Hip Arthroplasty with a Porous-Coated Acetabular Component. A Concise Follow-up, at a Minimum of Twenty Years, of Previous Reports by Craig J. Della Valle, Nathan W. Mesko, Laura Quigley, Aaron G. Rosenberg, Joshua J. Jacobs, and Jorge O. Galante. J Bone Joint Surg Am. 2009;91:1130-1135.
Published online: http://www.ejbjs.org:80/cgi/eletters/91/5/1130#10847

Book Chapters:

De Kam DCJ, Schreurs BW, De Waal Malefijt MC. Lange termijn complicaties na totale knie- of heupprothese. Het reumatologie en orthopedie formularium. Bohn Stafleu van Loghum. 2010.

Presentations:
2007: Nijmegen Hip Course 2007 (Nijmegen): The Exeter prosthesis in young patients.

2007: NOV najaarsvergadering (Veldhoven): Resultaten van de Exeter gecementeerde totale heupprothese bij patiënten onder de 40 jaar.

2008: Cursus Heupprothesiologie 2008 (Nijmegen): Gecementeerde heupprothesen bij jonge patiënten.

2008: Spine week 2008 (Genève, Zwitserland): Occipital condyle fractures; incidence, associated fractures and results of non-operative treatment.

2008: NOF congress 2008 (Amsterdam): Results of the Exeter hip prosthesis 2 to 12 years after surgery in patients under 40 years.

2009: Cursus Heupprothesiologie 2009 (Nijmegen): Gecementeerde heupprothesen bij jonge patiënten.

2009: AAOS annual meeting 2009 (Las Vegas, USA): Cemented polyethylene cups in patients under 40 years of age.

2009: EFORT congress 2009 (Wenen, Oostenrijk): (1) Cemented polyethylene cups in patients under 40 years of age. (2) Revisions of extensive Paprosky type 2B-3B acetabular defects with bone impaction grafting and a cemented cup

2009: NOV najaarsvergadering 2009 (Veldhoven): 25 jaar ervaring met biologische reconstructies van acetabulaire defecten bij gecementeerde THP patiënten onder 50 jaar

2009: SEOHS 2009 (Nijmegen): (1) Gecementeerde totale heupprothesen bij patiënten onder de 50 jaar. (2)Patiënt tevredenheid na totale knie- en heupprothesen. (3) Occipitale condyl fracturen, klinisch relevant of niet?

2010: AAOS annual meeting 2010 (New Orleans, USA): Ten years results of Cemented Total Hip Arthroplasty in Patients under 40 Years.

2010: EFORT congress 2010 (Madrid Spain): (1) The outcome of total hip arthroplasties in patients under the age of 50 years, a literature review. (2) Cemented revision hip arthroplasty in patients younger than 60 years, a follow-up study of 146 revisions. (3) Survival of 343 cemented total hip arthroplasties in patients <50 years and the results of their revisions.

Curriculum Vitae

Daniël de Kam werd als tweede van 6 kinderen geboren op 20 september 1983 in het Zeeuwse Vlissingen. Na een onbezorgde jeugd in Vlissingen ging hij naar het Voorbereidend Wetenschappelijk Onderwijs op het Christelijke Scholengemeenschap Walcheren in Middelburg. Na het behalen van zijn VWO diploma in 2001 verhuisde hij naar het verre oosten om Geneeskunde te studeren aan de Radboud Universiteit in Nijmegen. Tijdens zijn studie werd zijn voorliefde voor de orthopedische chirurgie alleen maar versterkt. Interesse voor wetenschappelijk onderzoek ontstond tijdens zijn wetenschappelijke stage bij dr. Schreurs van de afdeling orthopedie van het UMC St Radboud te Nijmegen. Aansluitend aan zijn artsendiploma in 2007 heeft hij als arts-onderzoeker gewerkt in het UMC St Radboud om de resultaten van totale heupprothesen bij jonge patiënten in kaart te brengen. In deze periode heeft al het onderzoek kunnen verrichten dat ten grondslag ligt aan dit proefschrift. Zijn onderzoeksperiode is enkele maanden onderbroken om als arts-assistent niet in opleiding (ANIOS) orthopedie in het UMC St Radboud klinische ervaring op te doen. Per januari 2010 is hij als arts-assistent in opleiding (AIOS) Orthopedie begonnen met zijn vooropleiding Heelkunde aan het UMC St Radboud (opleider orthopedie: Prof. Dr. Van Kampen; opleider heelkunde: Prof. Dr. Van Laarhoven).

Daniël is heel gelukkig getrouwd met Christa de Kam-Boogaard. Tijdens zijn coassistentschappen van de opleiding geneeskunde kregen Daniël en Christa hun eerste kind Nathan (2006) en tijdens zijn onderzoeksperiode werd het gezin aangevuld met Evelien (2009).

Sponsors

Sponsors

Publication of this thesis was financially supported by:

Anna Fonds te Leiden

Bauerfeind Benelux

DePuy - Johnson & Johnson Medical BV

Merck Sharp and Dohme BV

Nederlandse Ortopaedische Vereniging

Oudshoorn chirurgische techniek BV

Reumafonds

Stryker Europe

Their support is gratefully acknowledged